HIGHWAY PLANNING FOR

TRAFFIC HAZARD ELIMINATION

A THESIS

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by

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PREFACE

There are many technical matters involved in Highway Transportation, among which are Engineering, Statistics, Finance and Accounting. It is with the former of these - "Engineering" for Safety - that this thesis is concerned.

The writer has attempted to present in logical sequence, the compilation of certain data vital to accidents, the analysis of these data, and the use to which this analyzed information can be put when the subject is intelligently pursued with engineering foresight.

The writer has been connected in an official engineering capacity, with the Highway Planning Survey, since January of 1937. To the writer's knowledge, there is no assembled information in existence which treats of the studies made by the Planning Surveys for the elimination of Traffic Hazards and for the practical use to which these studies can be put and are being put, to reduce the accident toll on our highways.

Harold Berg

May 15, 1942

ACKNOWLEDGMENTS

Upon the completion of this thesis, I wish to express my most sincere appreciation to Professor F. C. Snow, to Professor John L. Daniel and to the Graduate Committee, the cooperation and assistance of each of whom has made this writing possible. I further wish to extend my appreciation to the various State and Federal Officials whose cheerful donation of technical matter has been of great assistance in completing this thesis.

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INTRODUCTION

A great deal of publicity and emphasis has been given of late to the safety of the highways. No highway policy which ignores safety can be adequate. Even though drivers are wholly or partly responsible for almost every highway accident, no highway administrator is justified in permitting the matter to rest unsolved. No highway can be foolproof; nevertheless some few things can be done to aid the poorest driver to drive safely and to protect others from him.

There are some locations on our highways where the accident frequency is abnormally high. Perhaps some element of surprise or confusion has been unwittingly introduced into the design at these locations and is not readily apparent to the highway engineer. To find the fault when only a few drivers out of hundreds of thousands find the situation too difficult is not an easy task. But the task must be accomplished.

Everyone who has thoroughly studied the matter of highway accidents is convinced that there always will be an irreducible number of accidents and has accepted this as a normal condition. As long as human beings have the freedom on the highways which they now enjoy, it is to be expected that some will go beyond reasonable limits in the exercise of that freedom and that others will make mistakes in judgment and suffer lapses in attention. Higher speeds, increased traffic volume, increased night driving, and a slower rate of increase of road space, which means less road space per vehicle, can be expected to keep the accident rate high for many years.

Yet despite these obstacles to safety, traffic accidents must be reduced to a minimum. Highway planning for the elimination of traffic hazards is the only rational means for achieving this end. It will be the purpose of this thesis to discuss the problem of accidents in its relation to changing highway transportation, to show how surveys for improving roads and road markings are made, and to discuss in detail the various methods that have been advanced for making our highways safer.

HIGHWAY PLANNING FOR TRAFFIC HAZARD ELIMINATION

CHAPTER I

DEVELOPMENT OF HIGHWAY TRANSPORTATION SINCE 1928

Highway transportation has developed and continues to develop with remarkable rapidity. The mushroom growth of automobile usage has changed our concept of time and distance. With our present 30,000,000 motor vehicles, the entire population of America could be transported to a central place within a week. In less time than that our nation would be in distress were motor transportation to stop. During the past decade some major features of this vast development of highway transportation have become much clearer. The rapid highway extension that continued for twenty years now has become slower and has been modified by an increased need for reconstruction to better standards. A better concept of highway traffic operating revenue has developed; safety has become more urgent; the need for better city by-passes and secondary roads has become more pressing.

The use of highways has increased about 73 percent in ten years; many city street patterns are out-moded, and traffic in the larger metropolitan areas of this country is becoming a dominant problem. In 1938 we had 4,224,031 motor trucks, with a total of 7,200,000 rated tons capacity, this tonnage capacity having increased 20 percent in the three preceding years. Where origin-and-destination handling of any freight is important, truck use will continue to increase, but truck use is influenced by road congestion, and helps to cause it. Increasingly more financial responsibility will be required of commercial truck operators, so that ultimately the progressively higher licensing fees for trucks will bring legitimate demands from owners for better truck-service roads, and especially for easier grades.

Of course, the general trend in highway transportation over the period 1928 to the present has been upward. There are more miles of improved road, more operating units, more traffic miles per unit, and consequently there is much more money involved. Unfortunately, there are also more accidents anddeaths. The same trend is shown by the increase in the precentage of truck registration, beginning about 1932.

Relations that always seem to hold true are typified by the relation of the number of deaths and accidents to operating mileage -- or say, per one million car-miles. The relation between total registration of vehicles and the economic condition of the country for short periods is less fixed, but quite definite. The invariably prompt recovery of traffic with business recovery is especially noticeable. The lengths of trips made by the same percentage of a given million motorists also tend to remain constant from place to place, and from year to year.

Examples of critical values of varying transport magnitudes are afforded by such quantities as the limiting percentage of grade for trucks, the limiting safe speed for automobiles on curves, the density of traffic when the roads become congested, and fundamentally, the number of miles of road per State or County that the operating revenue can support.

For traffic in volume, traffic circles and clover-leaf intersections have been designed. Improvements such as separate traffic lanes, traffic stripes, widening of traffic lanes from 9 feet to 10 and 11 feet, the introduction of artificial lighting at the more critical points, and the recognition and development of the proper relation of superhighways or freeways to other highways have made marked advances. The increased fatalities are causing us to give more attention to elimination of railroad crossings at grade and even to highway intersection at grade. Pending the elimination of grade crossings, it is necessary to resort to flashing light signals in a great many cases. Tunnels are being introduced in the western mountain states to reduce grade and curvature. Profiles are being designed with the purpose of eliminating headlight glare where traffic is in volume. The limiting effects of steep grades on truck traffic is prevalent, but it is necessary to face the facts that with the increased hill climbing capacity of the present passenger cars, the cost of reducing grades is due to truck traffic.

Insofar as the operation of the individual car is concerned, the details of design and construction have been vastly improved since 1927. Smoother riding surfaces, with non-skid texture, are conspicuous. Development of roadmix and plant-mix tops made with liquid asphalts and finer graded local materials has been remarkable - probably one of the most significant general advances since the time of Macadam. The more recent practices have been improved by full width base courses and the elimination of the old trench-section. Due to the development, in California and Oregon, of the "delayed finish" method of improving the Portland cement surface, it is now possible to make roads smooth to less than one-tenth inch variation in 10 feet. Transverse shrinkage cracks have been eliminated by the dummy, or weakened plane joint, and load transfer devices at expansion joints have reduced corner cracks.

The present standards are in theory quite satisfactory for traffic in volume and for the individual car. The use of transition curves or spirals has been established. A more satisfactory relation between superelevation and speed furnishes correct transition with the use of longer radii and the spirals. The wider traffic lanes and the spiral transition and less curvature rates also largely eliminate the need for pavement widening.

The question of safety on the more important metropolitan boulevards has been given increasing attention with emphasis on divided highway design. Associated with any multiple-lane highway is the elimination of cross-traffic which is now being understood more clearly. Here arises the need for side or adjoined service roads and the corresponding need for the wide right of way.

In the modern car we see the four-wheeled brakes, the higher performance and finer riding, its better steering, hill climbing, speed, and ease of control, all of which have been greatly improved within twelve years. We realize that vehicles will travel sixty miles per hour without effort and that drivers like this speed, especially between distant cities. We know that newer cars can negotiate 10 percent grades, and that the modern tire sticks well to the road, favoring shorter stops in emergency and better protection against weather. New designs in bodies include lower clearance doors and lowered centers of gravity that make for safety.

Many highways of the present day are choked with traffic. It has been impossible for the highway engineer to anticipate the legislative and vehicle changes which have occurred in the last twenty years. The geometry of the design of highways could not be based on speeds of 60 miles per hour when the law made 45 or less a maximum. For automobiles, we are now compelled to design longer vertical curves for two-lane highways mostly on the theory of possible collisions due to illegal passing at the summits. Such long vertical curves result in expensive grading in heavy country. This does reduce grades, however, and materially benefits truck operation.

The needs most especially important for expensive multiple-lane construction is an accurate forecast of the motor traffic loads 10 years hence. We also need to know the corresponding probable revenue for the budget.

The rate of truck increase is significant, now already averaging one in seven vehicles on the main highways. An outstanding opportunity for cooperation between the highway engineer and the automotive designers is the design of a better hill climbing truck - one which will permit the increase in grades above the present standards of five and six percent. In this event, a great deal of economy can be obtained in future mountain grading. In this same connection, it becomes apparent that the determination of proper tax rate for trucks of varying capacity and the corresponding control of overloads becomes vitally important. With constantly improving design, and with the corresponding increase of traffic, the highway engineer has seen with increasing clearness the defects of earlier work. His dominat feeling has been a wish that the public mind had earlier permitted higher standards.

For a number of years, the highway officials and engineers have conducted factual studies on limited and meager budgets. However, in the summer of 1934 the National Congress enacted the Hayden-Cartwright Act, providing for a direct grant to the several states and further permitting the use of one and one-half percent of Federal Highway funds for the use of economic and engineering fact-finding studies.

Highway Planning Surveys are now being conducted by 46 state highway departments in cooperation with the Public Roads Administration of the Federal Works Agency. These surveys consist of a series of related, continuing, fact-finding surveys designed to provide a basis for planning an adequate, safe, economically and socially defensible, integrated highway system.

In summing up and looking ahead, from twelve years of the past, certain general conclusions seem clear. In the building of main rural highways we have been out of the mud for several years. There now is a trend toward a larger mileage of roads under State jurisdiction. Unfortunately, it is not yet paralleled by a larger State share of revenues. Meanwhile the States are confronted with exacting demands for increased speed and volume with safety on the main highways. There also is a marked shift away from local taxation for highways and toward operating revenue support only. For the whole of the United States the total annual State license and gas revenue now runs to more than a billion dollars, but is subject to constant diversion for other than highway purposes. There are also rebate abuses that cause economic loss. Both defects need correction.

In the past the rates on motor fuel and other rates have been governed largely by precedent from state to state. We now need a more precise and discriminating measurement of these operating revenues. We shall thus be led increasingly into a rate-making procedure. An equitable division of operating revenues as between, say, state highways, metropolitan highways, and secondary or local roads also is inevitable. Fortunately, the Highway Planning Survey will furnish much of the needed basic information. In particular it will show the mileage we can afford to own and operate. There will come a time finally when maintenance and upkeep of established roads will require all the operating revenue. We must frankly face the interval of construction in the light of this fact.

Obviously, through the planning survey data, we are now able to make a fairly accurate forecast of the motor traffic loads 10 years hence. We are also in position to know the corresponding probable revenue for the budget. These needs are especially important for expensive multiple-lane construction, particularly in metropolitan areas for the vigorous attack on the problem of cross-city through-traffic. There are some bad inherited traffic conditions to cope with in cities. To build underpasses, for example, with 14-foot clearance involves often the contradiction of interference with four city blocks of property or the use of eight percent grades which are bad for trucks. The public must be enlightened as to the necessary costs and service and available revenues. The delays in property takings must be understood. From these metropolitan areas there is being gained, however, much useful information for future design. Present studies in our major cities are bringing remarkable results. The scientific advance toward safe and orderly progress in the ensuing years of Highway Transportation now rests entirely upon the Planning Survey Divisions of the individual states.

CHAPTER II

THE PROBLEM OF HIGHWAY ACCIDENTS

For the past fifteen or twenty years the highway engineer has been studying, worrying, and struggling with the "accident problem" on highways. Only recently has it occurred to him or evolved that this is not a true "accident problem", but instead that the accident factor is a "Transportation Problem" - a problem to be dealt with from the standpoint of Transportation. Since this discovery, with this new light being cast on the subject, the highway engineer has begun to unravel the problem, to see the flaws in the past construction and design, and to recommend steps which will ultimately give the public more safety on the roads and more roads for safety. Vitally important facts have come to light in recent investigations - facts which have lain dormant beneath the surface of highway research for these past years.

Through extensive campaigns, through the addition of more policemen, through intimidation of the public and the driver, the policing system in the past has forced safety upon a guarded few of the millions of drivers. It is now becoming apparent that this means of enforcement of safety measures is obsolete, that it angers the public and causes them to heap their abuse upon the officers so engaged to protect the public safety.

A new method of safety teaching is now in progress - the education of the driver and the public to the rules of the highway - their education to safety, and the education of the highway engineer toward the design of a highway on which the public will be safe even under extreme cases of carelessness, drunkenness, bad weather, and so forth. The fact that the public is becoming aroused to the safety of design of the highways is best illustrated by the following incident.

A certain highway engineer in an official capacity was designing a bridge to provide passage for a four-lane divided roadway. The roadway, being divided to the bridge by a twenty foot neutral strip, was to be more emphatically separated upon the bridge; therefore concrete pillar separators at each end of the bridge were erected.

It chanced that a "traffic safety man", upon seeing the design, questioned the need and practicability of the concrete pillars for separation. It was his argument that the pillar presented a traffic hazard to the public and would at some time be a cause of a serious accident. The designer, satisfied with his design, ventured the opinion that for the average driver this was a safe design and that only an intoxicated or extremely careless driver could strike the concrete structure.

The subject was dropped; the structure was built, and after a period of approximately a year, the "traffic safety man" again returned to this official on a business call. His first expression of interest was as to whether the bridge so designed previously had met all expectations and had been a safe design so far. The official, greatly perturbed, stated that not a week earlier a carload of men and women, driven by an intoxicated man, had struck the concrete pillar separators, killing every person. With the death of these people, the public immediately recognized the hazards in this bridge design. There was genuine public clamor for the removal of all public officials so connected with the hazardous design.

Upon the "traffic safety man's" statement - "I thought you said last year that the only driver who'd be apt to hit that obstruction would be a drunk man", the official could only say, "Yes, that's true, but now he and four others are dead".

This brings home to us the fact that the highway engineer must now design and is designing roads of such character and model that the possibility of an accident being had by anyone, in any condition, will steadily decrease.

Improvements to Reduce Traffic Accidents

In recent studies made on accident experience on the New Jersey State Highway System, the following conclusions were reached:

Accident Location and Time of Occurrence: Of the total accidents on the State Highways, 40 percent occurred at street intersections and the remaining 60 percent at intermediate points. Accidents occurring at night equalled 46.3 percent of the total, whereas those occurring during hours of daylight represented the remaining 53.7 percent. In spite of the fact that approximately one-fifth of the twenty-four hour traffic represents night travel, this one-fifth is responsible for approximately one-half of the accidents. Roughly speaking, it is therefore three times more hazardous to drive at night than during the day.

Accidents per Million Vehicle Miles: The average accident rate was found to be 3.10 per million vehicle miles. The accident rate on two-lane roadways was found to be 2.75, on three-lane roadways 3.53, and on four-lane roadways 3.61 accidents per million vehicle miles. In other words, an increased highway width resulted in an increased accident rate. It was interesting to find that, contrary to common belief, four-lane highways of the undivided type are more hazardous than three-lane roadways. It was found that the percentage of right angle collisions decreased with the width of the highway as did head-on collisions and collisions with fixed objects. However, same direction accidents increased with width.

Intersections: It has long been realized that intersections have serious effects on traffic volume and the number of the accidents. The problem of intersections has been approached from various angles such as signal lights, policing, striping, extra widening, elimination of left turns, and so forth. Yet the intersection problem remains, and today engineers realize that the intersection cannot be bettered materially except by one method, and that is by complete elimination. Numerous intersections could be eliminated, and their elimination would materially aid traffic flow, for the average intersection cuts down the normal traffic volume of a street to at least twenty-five percent.

Numerous cities have experimented with intersection elimination and have found some measure of success. The need for such elimination has been one of the causes for the introduction of one-way streets - streets on which traffic could move rapidly to and from the urban business sections of the cities. The introduction of the one-way street has met with considerable opposition from the merchant, but by proper education and presentation of facts, merchants have been won over to the new transportation method and have profited by it in increased business.

Information relative to highway crossing fatalities before these crossings were improved by clover leaves, traffic circles, and grade separations likewise has been lacking in the past, but from comparisons with other existing crossings at the present time, it was found that there is an enormous difference in the number of fatalities at the crossing and at the constructed clover leaf, traffic circle or grade separations.

Highway Lighting: There is a definite relationship between highway lighting and highway accidents. In general, where highway lighting is adequately provided, there is a substantial reduction in night accidents. The reduction results in a saving in all cases in excess of the cost of providing street lighting, not to mention the reduced suffering and anguish accompanying motor vehicle accidents.

Safety on the streets and highways depends upon the application of proper safeguards as well as upon the use of proper "safe practices"; that is, unless and until the highways, as well as the motor vehicles, are provided with proper and adequate "safeguards", and the highway user performs safe-practices when making use of these facilities, the motor vehicle accident problem will not be solved.

Divisional Islands: These, usually a raised portion between two two-lane roadways for the purpose of keeping opposing lanes of traffic from conflicting, have been considered one of the primary safeguards for highway users. Interesting facts have been developed on this type highway, but due to the lack of data with reference to past fatalities on these highways, the recently obtained information on the new divided highways has no basis for comparison.

Other Improvements

Of the numerous other improvements which may be classed as major factors in the elimination of highway accidents, the following are gaining in popularity by leaps and bounds: better sight distance at curves and hills as well as at street intersections; flatter curves and crowns; shoulders of sufficient width to permit vehicles to park off the traveled part of the highway; the proper use of standard signs, signals and markings, enlarged signs and striping of no-passing zones; the widening of pavements on the right side for slow uphill traffic; and the use of reflectors for roadside delineation for night driving.

CHAPTER III

CONDUCTING A CRITICAL FEATURES SURVEY

General highway planning in its entire scope covers a great many phases of planning, all directly connected with the highway and its supporters and users. Probably considered as one of the most important functions of the Planning Division of the Highway Department is its Critical Features Study.

The critical Features Survey, with the never ceasing thought of safety for the automobile user in mind, has as its primary duty the inventory of all restricted sight distances, excessive curvatures, superelevation of curves, and excessive gradients. The data obtained in this survey, in conjunction with other available information, will permit of a comprehensive study in the interest of safety for future highway development and improvement.

Organization

The general organization of the Critical Features Survey party consists of:

(1) Chief of Party - This man, experienced and trained in the work, has complete charge of the party. His responsibilities consist of proper interpretation of instructions by those under him, proper accumulation of data, progress of the survey, and the actions of himself and the men.

(2) Assistant Chief of Party - This man will head a unit under instructions from the Chief of Party, and will be responsible to the Chief of Party for his unit and its progress and share of the work.

(3) Recorders - Two recorders shall record, on especially printed forms, all notes of the Survey and shall also perform such other duties as may be assigned to them by the Chief of Party or his assistant.

Equipment

The survey is conducted by the use of two station wagons, properly equipped as follows:

Leading Car

1. Station wagon equipped with an odometer which measures to one one-hundredth of a mile.
2. One hand compass.
3. One stadia rod, mounted on rear.
4. Maps showing road numbers, project numbers, and counties.
5. Three signal lights, mounted on rear of top.
6. One 50-foot metallic tape (tenths).
7. One tire gauge (Shraeder).
8. One six foot rule.
9. One box letter file.
10. Stationery, report forms, pencils, erasers, etc.
11. Two clip boards for note sheets.
12. Three red flags, 24 inches square (two to mount on car, one extra).
13. One six-inch engineer's scale.
14. One loose leaf note book, with fillers.
15. One fire extinguisher.
16. One six-inch triangle.

Rear Car

1. Station wagon equipped with an odometer which measures to one one-hundredth of a mile.
2. One footometer with fifth wheel.
3. One directional gyro compass.
4. One hand compass.
5. One tapley meter.
6. One stadia interceptor bar, mounted on front.
7. Three signal lights, mounted on front of top.
8. One straight edge, equipped with level and gauge for superelevation.
9. One 50-foot metallic tape (tenths) anf two extra fillers.
10. One tire gauge (Schraeder).
11. One six-foot rule.
12. One hand level.
13. One three-foot light Philadelphia level road (telescopic).
14. One engineer's 100-foot steel chain.
15. One plumb bob.
16. Stationery, report forms, pencils, erasers, etc.
17. Two box letter files.
18. Two clip boards for note sheets.
19. One binder for note sheets.
20. One six-inch engineer's scale.
21. Two triangles, six-inch and eight-inch.
22. One loose leaf note book, with fillers.
23. Three red flags, 24-inches square (two to mount on car, one extra).

24. Maps showing road numbers, project numbers, and counties.

25. One first aid kit.

26. One fire extinguisher.

The purpose of the special equipment, some developed entirely for its use on Critical Features Surveys, is explained here.

(a) Gyro Compass - This, an expensive and delicate instrument, includes a gyroscope, the spinning of which is governed by a vacuum attachment to the automobile engine. This instrument, located on the dashboard of the rear car (see photograph, page 20) is used in the place of a transit for reading the bearings of the tangents at the point of curvature (P.C.) and point of tangency (P.T.) of each curve to be recorded. Because of the magnetic field set up by the automobile engine, it has been found necessary to use the gyroscope compass, all others proving useless under these working conditions.

Even so, special care and adjustments are required in order to obtain accurate and uniform results with this instrument.

(b) Tapley Meter - This, an instrument for reading plus and minus gradients while in an automobile in motion, embodies the principle of the pendulum. See photograph, page 20, for position of this instrument on the dashboard of the rear car.

(c) Footometer - This, a fifth wheel, which can be raised from or lowered to the ground at will, measures in feet the traveled distance desired. The footometer is attached to the left side of the rear car, near the front.

(d) Stadia Rod - This rod, carried in a vertical position on the rear of the front car, is used in maintaining a 1,000 foot interval between the two cars. This 1,000 foot interval is obtained through the use of this Stadia Rod on the front car and the Stadia Interceptor on the front of the rear car. (See photograph, page 20.)

(e) Signals - In order to coordinate the forward and backward movements of the two cars, and otherwise to transmit signals each car is equipped with signal lights - red, green, and amber - mounted on the rear of the front car and on the front of the rear car.

(f) Superometer - This, an instrument designed by the Massachusetts Highway Planning Survey, is used for reading superelevations of curves of standard design while the car is in motion. This instrument is also mounted on the dashboard of the rear car. (See photograph, page 20.)

Field Procedure

The activities of the Critical Features Survey are to be confined to improved routes on the State and U. S. numbered systems, and to improved routes on the county road system deemed advisable by the Division of Highway Planning. Maps showing routes to be surveyed, county lines, project lengths, types of paving, and other information are furnished the party for its guidance.

The forms on which the Critical Features Survey data are to be recorded are of the printed type. The party is furnished with sufficient forms for a period of two weeks. Instructions for the recording of these forms are given in general here, although more specific and detailed instructions are brought out when the particular studies are under discussion.

For convenience in handling, the note sheets are numbered consecutively for each State or county road. The notes are broken and a new sheet taken when measurements on another road are started.

All entries are made from the bottom of the page upward, a description of the starting point being entered in the lower left corner of the page.

Odometer readings of the trip odometer are recorded for P.C.'s and P.T.'s of curves, for beginning of critical sight distances, for beginning and ending of gradients over five percent and over 500 feet in length, for State, County and corporate boundaries, for intersecting State and Federal roads, beginning and ending and kind of surface type changes, Federal and State project markers, and railroad crossings.

The direction of curve, right (R) or left (L), its length and sight distance, are recorded in the column to the right or to the left of the centerline, whatever the case may be. (See sample note sheet, page 22.)

The information to be obtained by the party, coming under several different studies, is obtained in accordance with the paragraphs set forth below under the head of that particular study.

Sight Distance

Tires, gasoline, and oil being checked, the two cars are driven to the starting of the day's work. Here, after a last minute of checking the instruments, red flags are prominently displayed on the front and rear of each car.

The lead car proceeds in the direction of the survey, driving in the right traffic lane, with the stadia rod extended. The rear car waits until the stadia interceptor registers 1,000-foot distance, then follows

DASHBOARD EQUIPMENT - REAR CAR

Shown above is a stadia interceptor, gyroscope, and other intricate instruments used by Highway Planning Surveys to determine excessive curves and grades, restricted sight distances, improper superelevation, and other data necessary in intelligently planning the elimination of hazards on highways.

the lead car, maintaining a distance slightly in excess of 1,000 feet. Upon approaching a possible critical sight distance, the lead car signals and slows to fifteen miles per hour, the rear car still maintaining the 1,000-foot distance interval. If inter-automobile visibility is uninterrupted, no sight distance recording is necessary, but if the driver of the lead car cannot see the rear car (rear view mirror being used), he comes to an immediate stop and awaits the reappearance of the rear car. A momentary disappearance of the rear car as the lead car passes over a sharp vertical curve or past a building or other obstacle does not, as a rule, determine the position of minimum sight distance.

The driver in the lead car continually uses his rear vision mirror in checking visibility of the rear car. Since the driver of the lead car is acquainted with the road ahead, as well as behind, he is able to estimate whether it is desirable and necessary to move forward beyond the original disappearance. He finds that it is frequently necessary to do this in order to determine the minimum sight distance. However, any such movement of the lead car must be duplicated by the rear car, and the signal for the desired movement must be given. In estimating the points of minimum sight distance the driver of the lead car must bear in mind that the lead car will be the same distance ahead of the intersection of gradients, or P.I., of a vertical curve as the rear car will be back of it. Consideration must be given to this fact in choosing the points of minimum sight distance.

Since sight distance is affected by such physical features as grass, crops, bushes, billboards, lines of guard rail posts, trees, buildings, et cetera, the party must continually be on the alert for restricted sight

SAMPLE NOTES

FORM HPS-205

STATE HIGHWAY BOARD OF GEORGIA
DIVISION OF HIGHWAY PLANNING
In Cooperation with U. S. Public Roads Administration

Page No. 68

U. S. Route 280

1-8 19 40

State Route 30

21° Clockwise Per Hr.
Gyroscope Creep

County No. ______ Car No. 1 S. R. Jones Car No. 2 John Doe

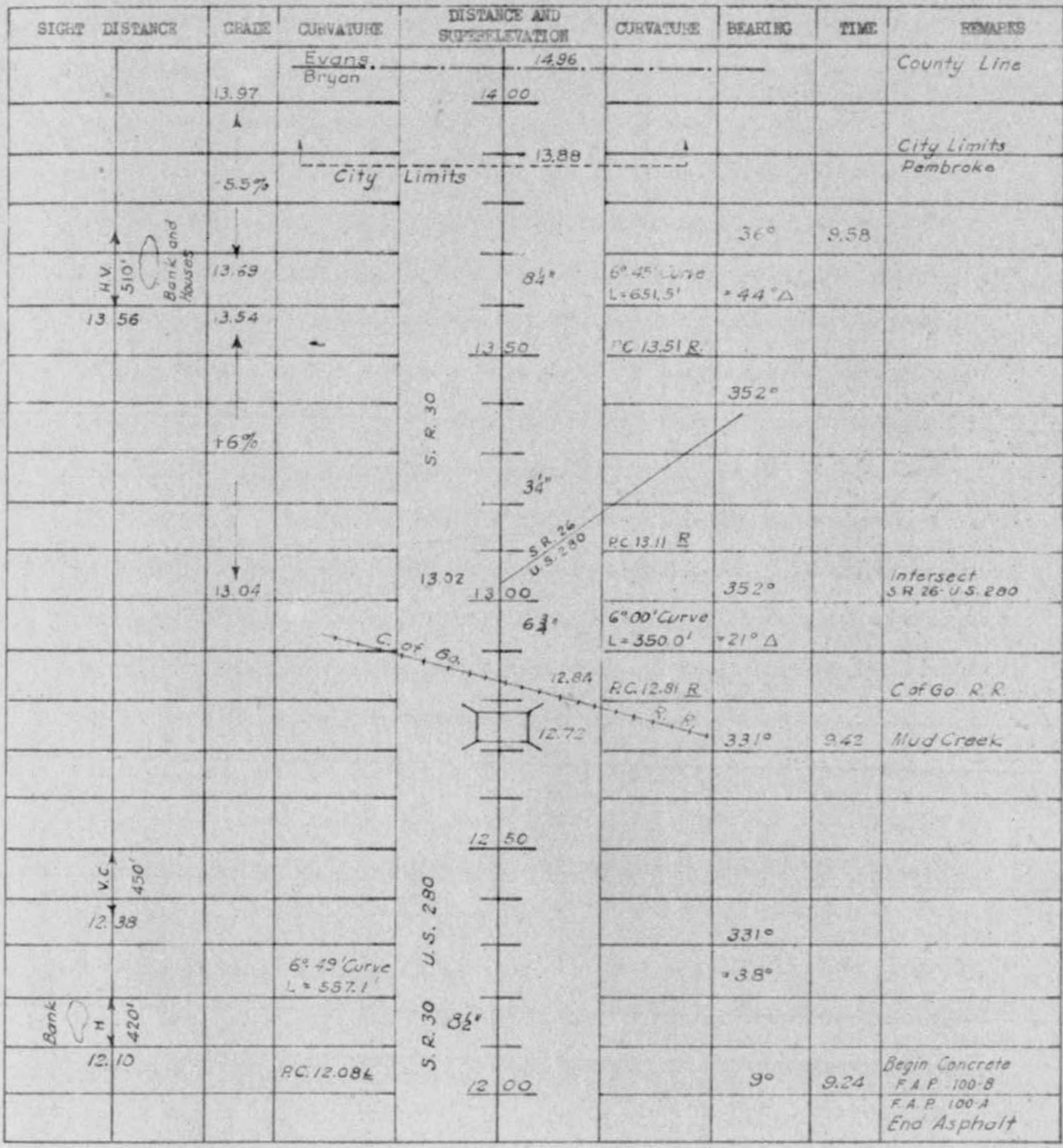
A. T. Smith

T. S. Jackson

John Doe
Chief of Party

Bryan
County

Sheet 10 of 10



distance caused by these features. In this survey, the Chief of Party must learn also to visualize how crops, bushes, trees, et cetera would appear during that season of the year when their foliage provides a maximum obstruction to sight distance. All these conditions are taken into account before recording sight distances. Such objects causing momentary interference in sight are noted, but sight distance is not measured.

(a) Sight Distance Determination - Figures 1, 2, 3, 4, and 5 (pages 25, 27, 29, and 30) illustrate how sight distances are determined. Figure 1 will serve to illustrate the detail of measurements: assume that the inventory cars are proceeding on the road from M to N, with the rear car following the lead car at an interval of 1,000 feet. When the lead car reaches point P-3, the rear car is at point P-1, and vision between the two cars is broken by obstacle R-1. The sight distance between these two cars at this moment is not the minimum, and the driver of the lead car therefore continues until he reaches a point P-4, which he estimates to be as far beyond the obstacle R-1 as the rear car will be back of the obstacle.

The driver of the lead car stops at the point P-4. He then switches on the signal light, thereby indicating to the driver of the rear car that he (the driver of the first car) is in a position for a sight distance reading. The driver of the rear car proceeds slowly until he first sees the signal light of the lead car. He then stops, sets his footometer at zero, and proceeds to the lead car. Upon arriving, he reads the footometer and records the minimum sight distance. After this recording, travel is resumed.

Where restricted sight distances and excessive curvature are common, the footometer is set at zero at the point of first occurence of either, and both are measured simultaneously. In such cases, it is necessary to calculate and record the lengths applying to each feature as the readings are completed.

The recorder notes the sight distance, the kind and direction of curve, or curves, and whether the principal cause of the obstruction is a horizontal or a vertical curve. These distances are entered on the printed note form.

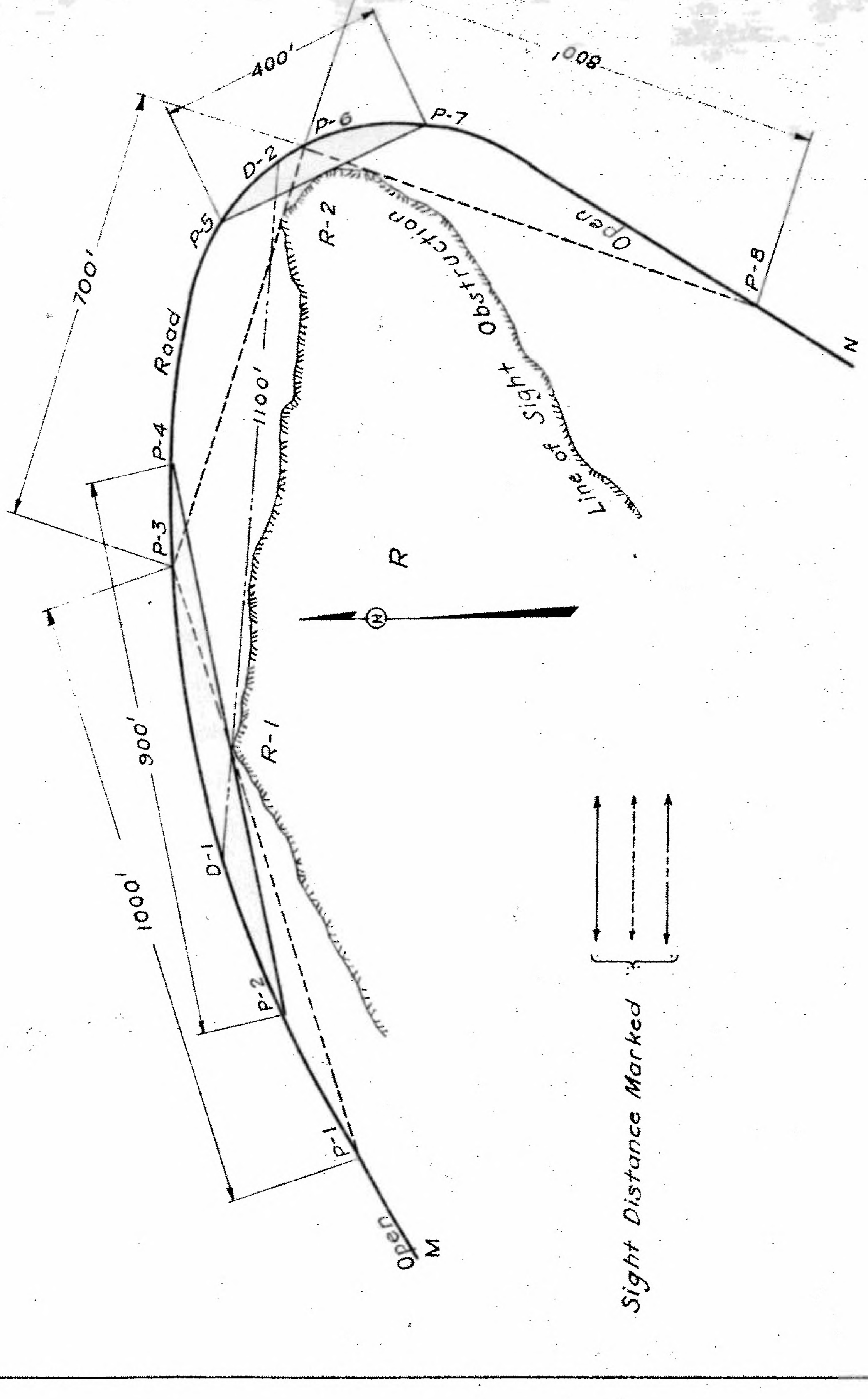
The minimum sight distance on the curve, illustrated next, will be caused by obstruction R-2. When the lead car leaves point P-4, it will be obvious to the rear crew that there will be another critical sight before the 1,000-foot interval of separation is attained; hence, it is not necessary for the rear car to lag behind to attain the 1,000-foot spacing. Experience in this manipulation will provide the necessary judgment for this maneuver. The driver of the lead car proceeds to point P-7 which is estimated to be same distance from R-2 that point P-5 will be from R-2. He stops at point P-7 and the method used to determine the sight distance is the same as that described above.

(b) Long Sections of Continuous Limited Sight Distance of Less than 1,000 Feet - Where a road is so winding and rolling as to cause continuous limitation of visibility of less than 1,000 feet, a sight distance for each controlling sight obstruction is recorded as in Figure 2, and the station limits within which the sight distances are less than 1,000 feet are also recorded.

No attempt to record continuous sight distance is made. On Figure 1, continuous limited sight distance would be P-1 to P-3, P-3 to P-6 to P-8. By this method the minimum sight distance P-5 to P-7 would not be recorded.

FIGURE 1.

Sight Distance Determination



There are two controlling obstructions, and if the sight distance P-5 to P-7 were shown, there would appear three limited sight distances, thus misrepresenting the condition. Then, too, the first point selected would control all the remaining distances. On Figure 3, six limited sight distances would appear, and yet the shortest sight distance for any given obstruction would not appear. This illustration serves to eliminate the question that might arise concerning the recording of continuous sight distance.

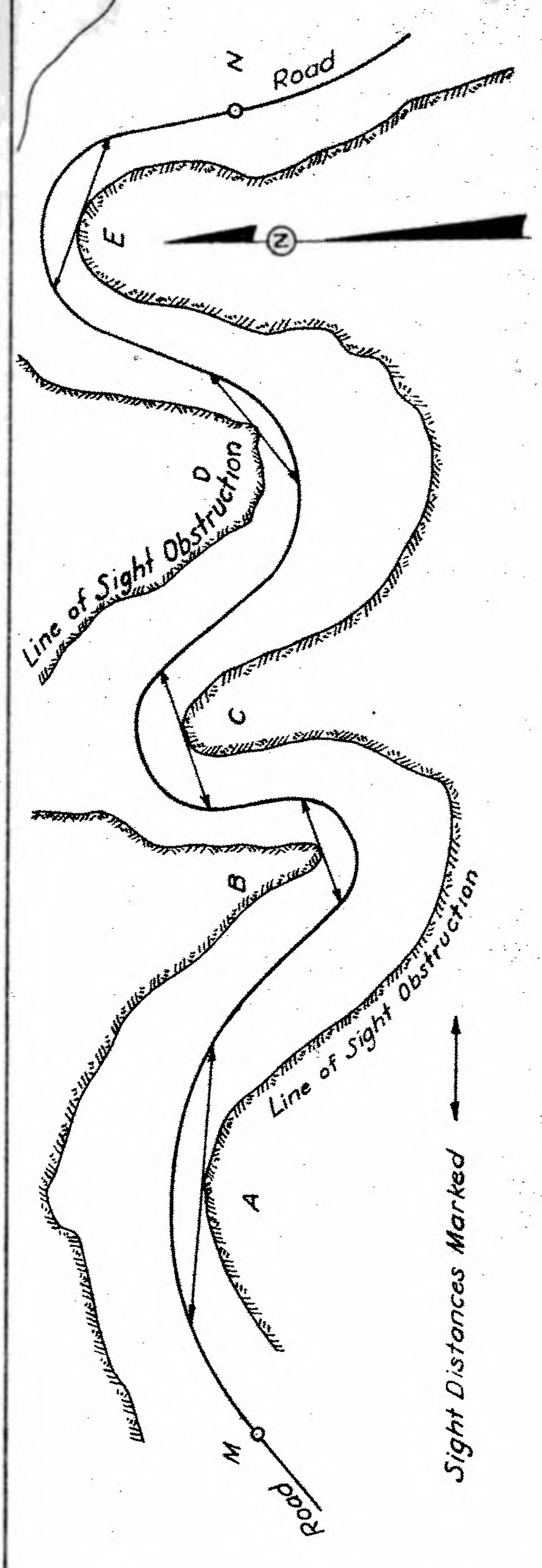
(c) Sight Distance Measurements on Combined Horizontal and Vertical Curves - Where a critical sight distance occurs at a location which is on both a horizontal and a vertical curve, the sight distance recorder observes which type of curve is most effective in limiting clear vision. He then records first, the type of curve which is the principal cause of sight interference; and second, the presence of the lesser interference caused by the other curve. EXAMPLE: A vertical curve as a governing obstruction is combined with a horizontal curve as a secondary obstruction. The recorder records VH, the minimum sight distance, and the nature of the horizontal obstruction. In cases where the horizontal obstruction prodominates, he records HV. Figure 4 shows a section of road from R to S, both in plain view, and in profile along the centerline. The limitation of sight resulting from the object F would be a minimum between points U and V, were it not for the vertical curve which causes a shorter view on this portion of the road.

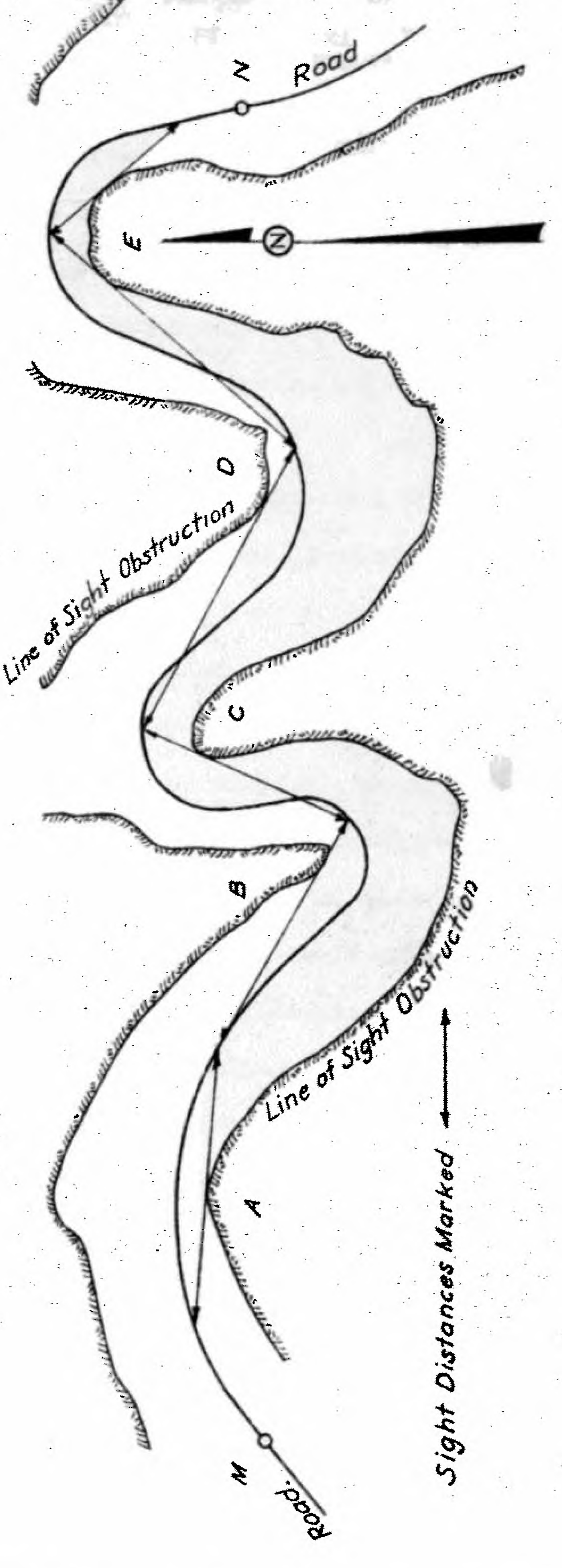
Figure 5A shows the approximate position of the lead car where vision is obstructed primarily by vertical curvature. Figure 5B shows the approximate position of the lead car where vision is obstructed primarily by

FIGURE 2

FIGURE 3

Long Sections of Continuous Limited Sight Distance





horizontal curvature.

On long compound curves, restricted sights at two or more points are recorded where sight distance limitations are caused by different objects, each of which constitutes an independent obstruction. Generally, but one observation is made on each vertical or horizontal curve.

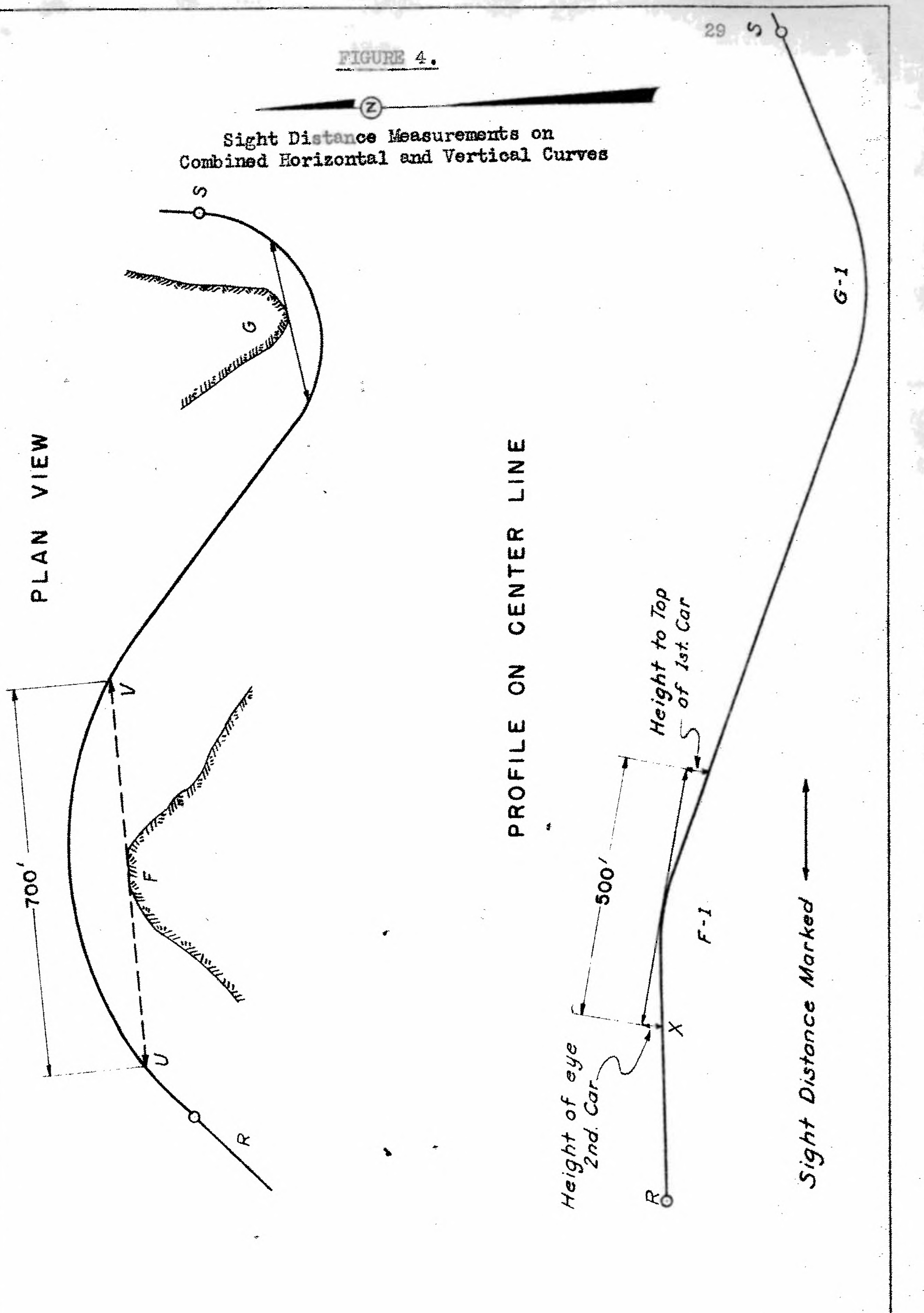
In the case of reverse curves, or of vertical and horizontal curves in close proximity, overlapping sights sometimes occur. In this case, it is necessary for the rear car, after having come up to the lead car to obtain the first measurement, to back to the beginning point of the second measurement after the lead car has proceeded forward to the point marking the end of the second measurement.

(d) <u>Corrections to Measurements Taken While Either Car Occupies a Road Shoulder or an Incorrect Lane</u> - Minimum sight distance past obstructions occurs from the inside lanes on horizontal curves. Since the survey is made by travel in one direction, the survey cars will occupy and take sight distance readings from the outside lanes on left curves. Also, in order to avoid danger to traffic by stopping the cars in traffic lanes, it is often necessary to turn out on the road shoulders or to the extreme side of the highway in making stops. When the cars are thus driven out to the side, the sight distances observed are shorter on right curves and longer on left curves than if taken from the correct position in the traffic lanes.

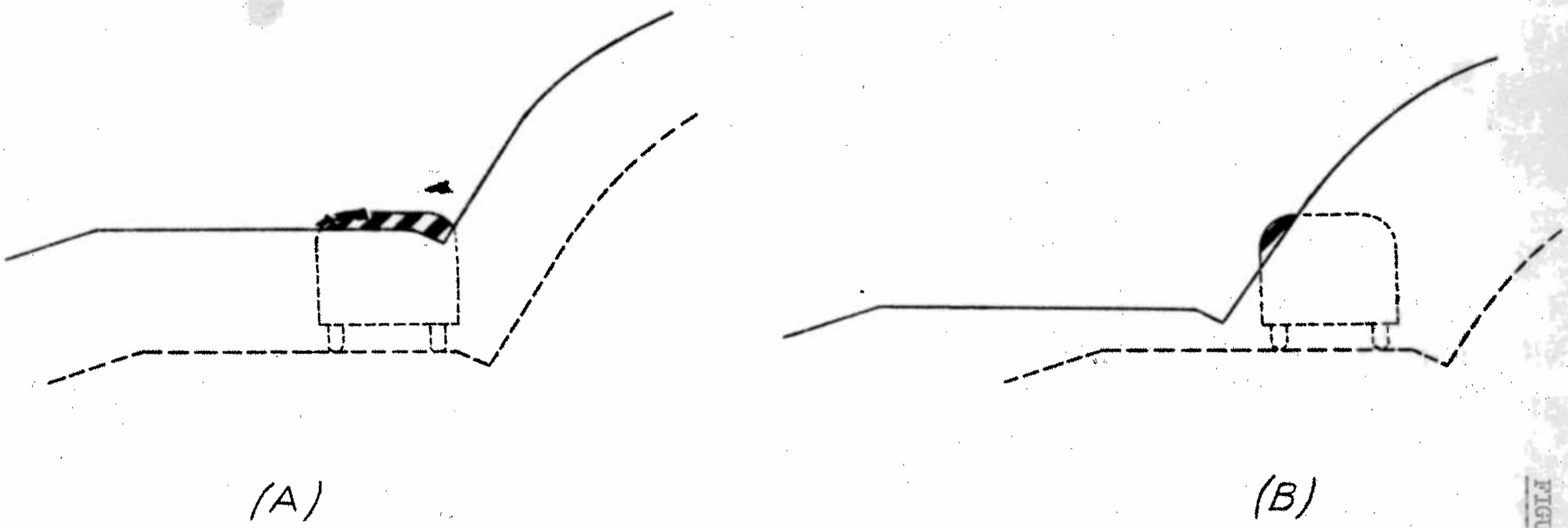
When either car must occupy the road shoulder on a right curve, the observer corrects the distance as read by adding the estimated distance back to the point where the car would have stopped had it remained in the traffic lane. Likewise, when either car must occupy the road shoulder on

FIGURE 4.

Sight Distance Measurements on
Combined Horizontal and Vertical Curves



Minimum Sight Distance Caused by Vertical and Horizontal Curves



Minimum Sight Distance
Caused By
(A) Vertical Curve
(B) Horizontal Curve

FIGURE 5.

a left curve, the observer corrects the distance as read by subtracting the estimated distance up to the point where the car would have stopped had it remained in the traffic lane.

(e) Crossings and Junctions - At all intersections of state routes, and at all intersections or junctions of state routes with important county roads, the approximate locations of objects sufficiently close to the intersection to restrict the view of cars approaching the intersecting road are sketched on the note sheet in their proper positions.

Excessive Grades

All gradients of 5 percent or over that extend for a greater distance than 500 feet are observed and recorded on the printed note sheet.

The tapley meter is used for the measurement of the percent grades. Installed on the steering post (See photograph, page 20), this instrument is in a position where it can be easily read by the operator. The meter readings are the direct per cent of grade. The meter is so constructed that when its face shows a black background, it indicates a minus grade, or that the car is traveling downhill; the white background indicates a plus grade, or that the car is traveling uphill. Since this meter is based on the pendulum principle, the operater must maintain a CONSTANT SPEED OF NOT OVER FIFTEEN MILES PER HOUR WHEN TAKING READINGS. If traffic or other conditions prevent maintaining a constant speed, the car is brought to a stop in order to secure a correct reading of the percent grade.

Slight breaks in a grade, even though averaging in excess of 5 percen with lengths less than 500 feet, are not considered. Grade measurements are taken over the full length of the slope where this slope exceeds the stated minimum grade.

The beginning and edning of a gradient are recorded by odometer readings, the plus or minus percent of the grade being noted in accordance with the direction of survey travel.

Superelevation

The superelevation is taken at a convenient point on each curve of 2 degrees or more and is recorded on the printed note sheet for the curve where taken. The Chief of Party readily learns to select curves of 2 degrees and over by observation. It is advisable at the beginning to compute degree of curvature in the field for a time, that is, until sufficiently accurate judgment is developed. The principal point to develop is the ability to judge curvature as being more or less than 2 degrees.

A ten-foot straightedge with level bubble and graduated scale attached is used. A superometer, installed in the rear car, is also used as a supplement to the straightedge on the more modern sections of road. In measuring the superelevation of a curve with the straightedge, the straightedge is placed on the radial line of the curve and brought to a level position, the graduated scale being set and read. This gives the number of inches and fractions of an inch of superelevation in ten feet, the direct reading being recorded. A sufficient number of measurements are taken in order to insure obtaining the typical superelevation for the curve being measured.

If the superelevation is to be read by use of the superometer, the reading may be made with the car in motion, the direct reading being recorded.

Excessive Curvature

Curve data are recorded on all curves of 5 degrees and sharper. As a preliminary step before the rear car leaves its starting place on the road to be surveyed, it is necessary to set the gyroscopic compass to the proper bearing of the initial tangent piece of road. Insofar as the gyroscopic compass requires resetting each time the engine is stopped, care must be taken on all stops to keep the motor running.

The bearing of the initial tangent is determined through the use of a hand compass, which when operated at the proper distance from the automobile is not affected by the magnetic field set up by the motor. From this bearing, so determined, the gyroscopic compass is set and the rear car is ready to proceed.

In surveying for excessive curvature, all observations and measurements are made during the regular survey of sight distances.

Measurements and observations recorded consist of the following and are obtained as explained below:

Upon approaching a curve which the Party Chief considers to be 5 degrees or sharper, the rear car is slowed almost to a stop, but proceeding forward and parallel to the tangent. Immediately prior to the estimated P.C. of the curve, the tangent bearing is read and recorded on the printed note sheet. The time of day at which this reading is taken is also entered on this same form in its proper place (See page 22).

When the P.C. is reached, the car is brought to a stop; the odometer reading is recorded, and the footometer, set at zero, is engaged by the Chief of Party. The direction of curve - right or left - is entered, and the car proceeds. When the P.T. is passed, the footometer, odometer, directional and time readings are made and recorded in the same manner as for the P.C., the footometer being disengaged at the P.T.

From these data are to be computed the central angle and length of curve of the surveyed curve, the degree of curve being computed from the formula

$$D = \frac{100 \text{ Delta}}{L}$$

and the curve length being the direct reading of the footometer between the P.C. and P.T.

For the purpose of determining the degree of curvature in the field, the amount of "creep" in the gyroscopic compass must be taken into consideration, because long curves sometimes contain sight obstructions which require ten or more minutes to record. For this reason, the recorder enters the time of day opposite the proper odometer reading, approximately every fifteen minutes during the day. This permits corrections for "creep" to be made in the office, and makes the notes available for plotting alignment on any section of road.

"Creep" in the gyro-compass, amounting to approximately 5 degrees every fifteen minutes, is due to the spinning motion of the gyroscope. The amount of creep is determined twice a week and is entered in the notes. The method of determining the amount of creep is as follows:

The pet cock, leading from the vacuum gauge, is opened until the needle registers a vacuum between three and five inches of mercury. After waiting five minutes for the motor to reach its spinning speed of 10,000 R.P.M., the caging knob of the gyro is pushed in, until it engages the synchronizer lever plunger; this knob is then turned until the desired azimuth is observed under the lubber line of the instrument. Next the caging knob is pulled out until it releases the caging mechanism, thus leaving the gyro free. At the expiration of exactly thirty minutes, the azimuth is reread. The difference in the two readings represents the amount of creep in the instrument.

CHAPTER IV

INTER-REGIONAL ROUTE CHARTS

The data compiled by the Critical Features Survey may be analyzed in various ways, depending on the type of information sought.

The present procedure for the studying of factors involved in accidents consists first of reference to the Critical Features Survey data. From this material and other data obtained in the Road Inventory Survey and Traffic Survey, it is possible to prepare charts such as that illustrated in Figure 6.

This chart is usually prepared concerning the highways of strategic importance, although sufficient data are available in the Planning Survey files to prepare such charts on any routes desired. Prepared at a horizontal scale of twenty miles to an inch, this chart shows the following data on the route in question: cities, rural and urban mileage, pavement widths and types, right-of-way width, excessive curves per mile, excessive grades per mile, restricted sight distance per mile, fatal accidents per mile, and foreign, commercial, and all-total traffic.

From a study of this chart, it is evident that over this route good pavement surface is encountered, all being 18 feet in width and built on a 60 to 100 foot right-of-way.

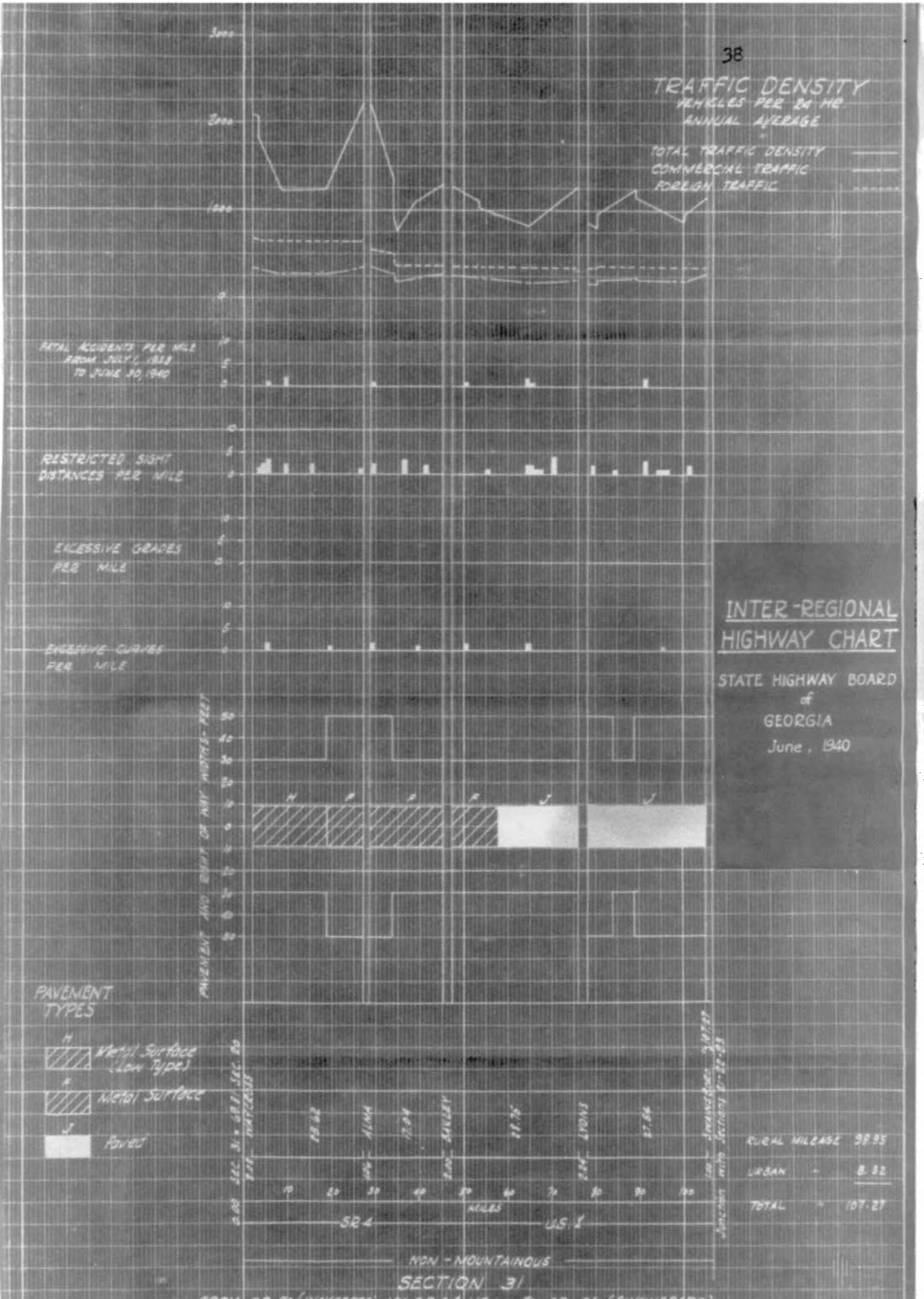
Excessive Curves Per Mile - Excessive curves, that is, curves of five degrees or sharper, although amounting to only eleven over the 107 mile route, have eight of these curves grouped in four miles, namely, mile 6, two curves; mile 29, two curves; mile 50, two curves; and mile 64, two curves. This is a condition dangerous in itself, because although the excessive curve rate for the total route length is very low, the excessive curve rate for certain miles is exceptionally high.

Consider the average driver on a long drive; his speed is held fairly constant, but long stretches of roads with no excessive curves have probably permitted him to increase his normal traveling speed. Upon his approaching an excessive curve, he slows his car, negotiating the curve safely; and because of the miles behind him on this same road, he probably immediately resumes his cruising speed. Now he approaches the second excessive curve so quickly after completing his first and probably at the point where he is just approaching his cruising speed. The driver probably is surprised, and he may become so confused that an accident results. Other drivers, approaching like conditions, may suffer a lapse in attention after negotiating the first excessive curve, and upon the sudden realization of a second curve being approached, may become confused and make mistakes in judgment simultaneously. The result may be an accident of some proportions.

Excessive Grades Per Mile - No excessive grades, that is grades of 5 percent for distances of 500 feet or more, exist on this route.

Restricted Sight Distances Per Mile - The chart presents a picture of numerous restricted sight distances, and in this case also these traffic hazards have tended to group. The restricted sight distance hazard is probably one of the most serious to be combatted in highway improvement for safety. Means of combatting this evil will be discussed later.

Traffic Density - A study of the traffic values or volume shown at the top of this chart brings out the fluctuations in the daily traffic volume. It is noted that the total traffic density fluctuates the greatest;



SECTION 31

FROM SR 50 (WAYCROSS) - VIA SR 4 & US 1 - TO SR 26 (SWAINSBORO) the commercial traffic fluctuates considerably,and the foreign traffic maintains a fairly level trend except when intersecting a city or some junctioning route.

Fatal Accidents Per Mile - The chart, prepared primarily to assist in analyzing the traffic accidents, has now had all of its symbols explained except the Fatal Accident data. These data, compiled from the State Highway Patrol information, shows the location and number of fatal accidents on this route. There may be as high as five or six non-fatal accidents for each fatal accident shown on this chart. These non-fatal accidents are not shown.

Inspection of the chart, considering all other charted items, now reveals the following facts: in mile 6 one fatal accident is shown. Over the same mile, approximately 1,600 vehicles travel daily, 650 of these cars being foreign traffic and 300 being trucks; pavement width is 18 feet; right-of-way 60 feet. There are no excessive grades, but there are two excessive curves and three restricted sight distances in this mile. In addition, sight distance has been restricted in several other cases on either side of this mile in which the fatal accident has occurred. From this observation we are led to believe that restricted sight distance and excessive curvature have had some influence in this accident.

In moving to mile 10, we find two fatal accidents have occurred here. Total traffic has decreased, although the foreign and commercial are practically at the same as in mile 6. But again we are confronted with the fact that there are two restricted sight distances in this mile.

Moving again, we reach the fatal accident in mile 30. This has occurred where traffic volume is high, pavement width and type are good, right-of-way is 100 feet, but excessive grades and restricted sight distances are again two each in this vicinity.

No let us approach the fatal accident situation in miles 65 and 66. In this case, we find that traffic is almost at the lowest, but our accidents are grouped just as our restricted sight distances and excessive curves are grouped in this same vicinity. Evidently, the drivers involved in these accidents were either confused or made a mistake in judgment in passing through this closely grouped nest of restricted sight distances and excessive curves. It is very fortunate that traffic volume has been so low where the fatal accident rate is so high.

The chart discussed above, after being analyzed, can be used in conjunction with critical features data and certain road inventory data for ascertaining just what those conditions are that cause the restricted sight distances. Upon proper study of this subject the Highway Engineer can determine the amount of work involved to correct the fault and eliminate the hazard of restricted sight. His only remedy for the excessive curvatures can be relocation of a flatter curve.

CHAPTER V

SEPARATING TRAFFIC ON MULTIPLE-LANE HIGHWAYS

The rapid and safe movement of motor vehicles from their origin to their destination is the primary thought of the Traffic and Safety Engineer. In order for this goal to be gained, these engineers have solved various problems, chief among which are the following:

Highways must be sufficiently wide to carry the traffic confined to them. These same highways must have sufficient sight distance to permit passing of the slower vehicle by the faster.

Means must be devised for separating the streams of opposing traffic, and especially so over hills and curves of restricted sight distance.

The solutions of each of these problems which have arisen have been arrived at in several different ways. Although the solutions may not have been exactly the same, it is without question that the factors involved in the solutions were all considered in the same light. Individual solutions may not conform to the generally accepted, and at present practiced solutions, but these latter are considered as solving the problem practically and economically and with excellent results.

Present methods for separating traffic on two or more lane highways consist of those presented and discussed in the following pages. The methods as discussed here are those which are generally being investigated and, at present, being put into use by the majority of State and City officials.

Striping

Striping or painting of a centerline stripe down the center of the highway has for several years been a means of separating opposing traffic. It has not been until recently that engineers of skill and foresight have urged the use of the no-passing stripe both for restricted sights on hills or curves, and for approaching intersections. With the recent advent or invention of beaded (luminous) paint it is entirely probable that striping as a means of separating opposing traffic will see greater use than has been anticipated.

Striping No-passing Zones in Opposite Directions: Passing or overtaking vehicles on two or three-lane roads is accomplished in a lane adjacent to that which may be occupied by a vehicle approaching from the opposite direction. Sufficient sight distance should be available before the passing maneuver takes place. However, few drivers are capable of judging a limited sight distance, and for this reason, it becomes necessary to make these restricted sight distances as no-passing zones. In order to provide a reasonable margin of safety in designing a highway, the minimum sight distance should be long enough to accommodate almost all vehicles, and the factors involved should be liberal.

In striping a highway to restrict passing of vehicles where sight distance is inadequate, the general concept in choosing factors is totally different from that in choosing factors for highway design. If the same factors are chosen and a highway is striped to restrict passing wherever the sight distance is less than the passing minimum, the highway is severely impaired, as almost all drivers accept the policy of remaining on the right of a restrictive stripe throughout its length.

The passing minimum sight distance used in design includes a distance traversed during a limited time. Because a driver can see a stripe at some distance, it is not necessary that this distance be included in the length of this restrictive stripe.

The minimum sight distance on which to base restrictive striping for a two or three-lane road is necessarily a compromise between the minimum sight distance used in design and sight distance of no appreciable length. The former, although on the side of safety, materially restricts the use of the road. The latter, although highly hazardous, does permit passing at will. Thus, if a driver sees only enough of the road ahead to pass a vehicle which is practically standing still in the face of opposing traffic, he is not deterred by the restrictive striping, even though he may be traveling at a very low speed himself.

The type of pass influences the required passing sight distance appreciably. The assumption of delayed passing is on the safe side, but if a road is striped on this basis, it may unduly impair the usefulness of the road because vehicles naturally pass without first reducing speed when the opposing traffic lane is clear of vehicles. Flying passes, or those not subject to delay by opposing traffic, occur with greater frequency on lightly traveled roads and on roads with a preponderance of traffic in one direction. Delayed passes, or those in which the pass is impeded by opposing traffic, become more numerous as traffic density increases.

Traffic conditions approaching a no-passing zone may be much more critical than those assumed. The speed of an overtaken vehicle may be much greater than that assumed, perhaps only ten miles per hour less than the assumed design speed of the road, and a flying pass may be impracticable due to opposing traffic. A passing maneuver under such circumstances should be begun a considerable distance back of the beginning of the restrictive stripe or the passing vehicle will not be able to return to the right lane before meeting an opposing vehicle traveling, say at the assumed design speed, which appears after the passing maneuver is begun. Safety under such conditions depends principally upon the judgment of the driver of the overtaking vehicle. He can be aided if the restrictive stripe is begun at the point where he normally would return to the right lane if conditions are as critical as those assumed for calculating minimum passing sight distance used in design of the road. If he judges that he cannot return to the right lane before the beginning of the stripe, the reasonably cautious driver will not pass the overtaken vehicle.

The sight distance for striping finally recommended in the column of Table I is a compromise based on a passing maneuver such that the frequency of maneuvers enabling passing where sight distances are shorter is not great enough to impair seriously the usefulness of the road. From inspection of this table, as prepared by the Public Roads Administration, it is noted that the sight distance for striping varies and is dependent on the design speed. The design speed, being greater than that used by almost all drivers on that particular section of road, when traffic is not heavy enough to impede smooth operation, is governed largely by the physical characteristics of the road, such as sharp curvature, and by the surroundings - wide open spaces encouraging higher speeds than the built-up areas. The assumed design speed is considered to be the maximum approximately uniform speed which probably will be adopted by the faster group of drivers, but not necessarily by the small percentage of reckless ones.

Terrain is an important factor affecting the choice of design speed. Under this factor, it is obvious that a rolling terrain will be much more favorable to a high design speed than will a mountainous terrain. An important highway carrying a large volume of traffic will justify a higher design speed than a less important highway in similar topography. A low design should not be assumed for a secondary road, however, if the topography is such that vehicle operators probably will travel at faster speeds on the finished road. Drivers do not adjust their speeds to the importance of the road, but rather to the grades, curves, and sight distance. It is therefore to be expected that a great many drivers, because of the lack of traffic on secondary roads, may actually drive faster there than on the more important, better, and more heavily traveled important routes. Because the assumed design speed should indicate the speed at which traffic may travel under fair conditions and with a reasonable degree of safety, and because no-passing zones are related to sight distances which in turn vary in accordance with the speed of travel, all roads or sections of roads should be classified for a design speed as a preliminary step toward striping.

The design speed of an existing road or section of road may be found by measuring the speed of travel when the road is not congested, plotting a curve relating speeds to numbers or percentages of vehicles and choosing a speed from the curve which is greater than the speed used by almost all drivers. The design speed may also be found by driving the road until a comfortable maximum speed is found, the average of several drivers and vehicles being desirable.

Sight distance ahead on a road is generally not the same as that to the rear. The usefulness of a road is seriously impaired if a stripe indicating a no-passing zone does not differentiate between opposing directions of travel, such as a single stripe on the centerline. In general, this also

TABLE I

RELATION OF LIMITS OF NO-PASSING ZONES TO P.I. OF VERTICAL CURVES FOR PURPOSE OF MARKING PAVEMENTS

DESIGN SPEED M.P.H.	MIN. PASSING SIGHT DISTANCE FOR MARKING PAVEMENTS	Value of Algebraic Difference of Grades, Percent ÷ 100											
		0.04		0.06		0.08		0.10		0.12		0.14	
		A	B	A	B	A	B	A	B	A	B	A	B
30	500	40	330 -170	160	390 -110	200	420 -80	280	440 -60	340	460 -40	390	490 -10
40	600	180	420 -180	310	480 -120	410	520 -80	525	580 -20	630	620 20	740	660 60
50	800	320	620 -180	500	700 -100	680	790 -10	860	860 60	1030	940 140	1200	1020 220
60	1000	600	820 -180	930	980 -20	1250	1120 120	1530	1260 260	1880	1400 400	2160	1540 540
70	1200	980	1060 -140	1480	1320 120	1970	1540 340	2460	1760 560				

A - Minimum length of vertical curve for minimum no-passing sight distance.
B - Horizontal Distance from P.I. of vertical curve to limits of no-passing zone.

The upper figure in each case is the distance in feet to the beginning of the no-passing zone. The lower figure is the distance to the end of the no-passing zone. When the lower figure is a minus value the end of the zone is on the near side of the P.I., the length of the no-passing zone is the difference of the two figures and there is a gap between the ends of no-passing zones in opposite directions. When the lower figure is a plus value the end of the zone is on the far side of the P.I., the length of the no-passing zone is the sum of the two figures and no-passing zones in opposite directions overlap.

causes a serious disrespect for restrictive stripes. When, for example, a highway is on tangent and the sight distance over a hill is inadequate for passing, the restrictive stripe should then begin where the sight distance is less than a desirable minimum, but beyond the crest where the road opens up to view, the stripe should not prohibit a vehicle from making a passing maneuver.

The purpose of the stripe should, however, be to prevent passing by vehicles in the opposite direction when approaching the crest. Using a system of striping, which restricts passing to traffic in one direction only is one method of attaining both objectives. This may be done by a dashed stripe throughout the centerline of the road with an additional continuous stripe on the side where sight distance is limited. No-passing zones in one direction may overlap another in the opposite direction, or there may be a gap between the ends of the zones. Such a system of striping as will differentiate between traffic in opposite directions will naturally show these overlaps and gaps. For example, a broken stripe centerline with a continuous stripe alongside to indicate a no-passing zone, would have a continuous stripe on both sides where the two no-passing zones overlap on a two-lane road.

Since passing on three-lane roads is accomplished in the middle lane, a system of no-passing marking must be adopted such that the middle lane may be used effectively; otherwise it serves no purpose at all. Confusion can be avoided, hazards diminished, and utility of the road increased by a system of striping which restricts traffic in one direction to one lane, but permits traffic in the opposite direction to use two lanes.

A great deal of question has arisen regarding the most desirable type of operation over the crest of a hill on three-lane roads. Some engineers recommend two lanes for uphill traffic because of the delay caused by the slow moving trucks. From the standpoint of sight distance, this becomes hazardous because it encourages passing with limited sight distance. It is generally felt, though, that passing should be confined to the right lane when sight distance is inadequate for passing, just as on two-lane roads. When the road ahead again opens up to view, the restrictions should be terminated and passing again permitted on the middle lane.

Diagonal striping should be so provided in the middle lane that the diagonal stripe crosses from the left lane line to the beginning of the restrictive striping on the right lane. This diagonal striping should meet the longitudinal restrictive striping at the beginning of the no-passing zone. It should inform drivers in one direction of the necessity of moving over to the right lane without crossing the diagonal striping but should not prevent crossing by vehicles traveling in the opposite direction. Figure 7 presents the approved standard striping practices and various other designs in use.

An idea of the location of no-passing zones at hill crests can be obtained from Table I, which shows their location for various changes in grade for which the lengths of vertical curve are those resulting in the minimum sight distance permitted by design.

Striping No-Passing Zones Approaching Intersections: It is desirable that vehicles on two or three-lane roads approaching an intersection keep to the right and that all passing maneuvers should be completed before reaching the intersection. Passing while crossing an intersection is hazardous because the passed vehicle may obstruct the view of the cross road to the right, the passed vehicle may turn left in front of the passing vehicle, and the driver of a passing vehicle may find it difficult to observe crossing and turning traffic at the same time that he is required to watch traffic ahead. Two or three-lane roads, therefore, should be striped to restrict passing for some distance each side of an intersection. Once beyond an intersection, there is no further need to restrict passing if sight distance and traffic conditions permit passing. The stripe, therefore, should restrict vehicles from passing approaching the intersection and not restrict passing beyond the intersection.

When one road at an intersection is a preference road and traffic on the non-preference road is stopped at the intersection, the use of restrictive striping on the preference road is open to serious question. There is some hazard in the possiblity of a left-turning vehicle cutting in front of a passing vehicle, but the hazard due to possible restriction of sight is nil. It appears to be inadvisable, therefore, to restrict the free movement of traffic on the preference road by the use of no-passing marking if not required otherwise.

Traffic should be restricted from passing while crossing a railroad at grade. While there is no left-turning traffic, the passed vehicle may obstruct the view of the signal and the track to the right. A restrictive stripe also has the desirable effect of lining up vehicles in the right lane when the crossing is closed so that traffic is free to move in both directions when the intersection is clear.

Normally the driver of a passing vehicle should return to the right lane before reaching the beginning of a restrictive stripe. The length of restrictive stripe at the approach to an intersection, therefore, is theoretically zero. The restrictive stripe should, however, be visible for some distance so that it is necessary to make it an arbitrary length, say 100 to 200

NO PASSING STRIPING - TWO-LANE ROADWAY

The above picture presents the restrictive stripes as applied to both lanes because of restricted sight distance around this curve.

feet. An appreciable length of restrictive stripe will also have the desirable effect of encouraging drivers, who normally return to the right lane some distance past the beginning of the stripe, to return to the right lane before reaching the intersection.

A restrictive stripe on a three-lane road approaching an intersection normally should be located on the right lane in the same manner as used at a location with short sight distance. This method lines up vehicles approaching the intersection and permits passing by vehicles leaving the intersection. Where vehicles are likely to be stopped, however, it may be desirable to locate the stripe on the centerline of pavement. If stopping is effected by continuous traffic light control, it may be desirable to limit striping to normal lane lines and omit restrictive stripes altogether. Passing may be accomplished when the light is green if sight distance and traffic conditions along the road are favorable, and two lanes in each direction may be used for storage when the light is red. If traffic is evenly divided in both directions, opposing traffic in the middle lane will have to free itself on the "Go" signal. When traffic is heavy, however, it generally is unbalanced and the omission of restrictive stripes may have the desirable effect of providing two lanes for storage and movement in one direction. At important intersections three-lane roads may be widened to four lanes and a restrictive stripe placed at the centerline.

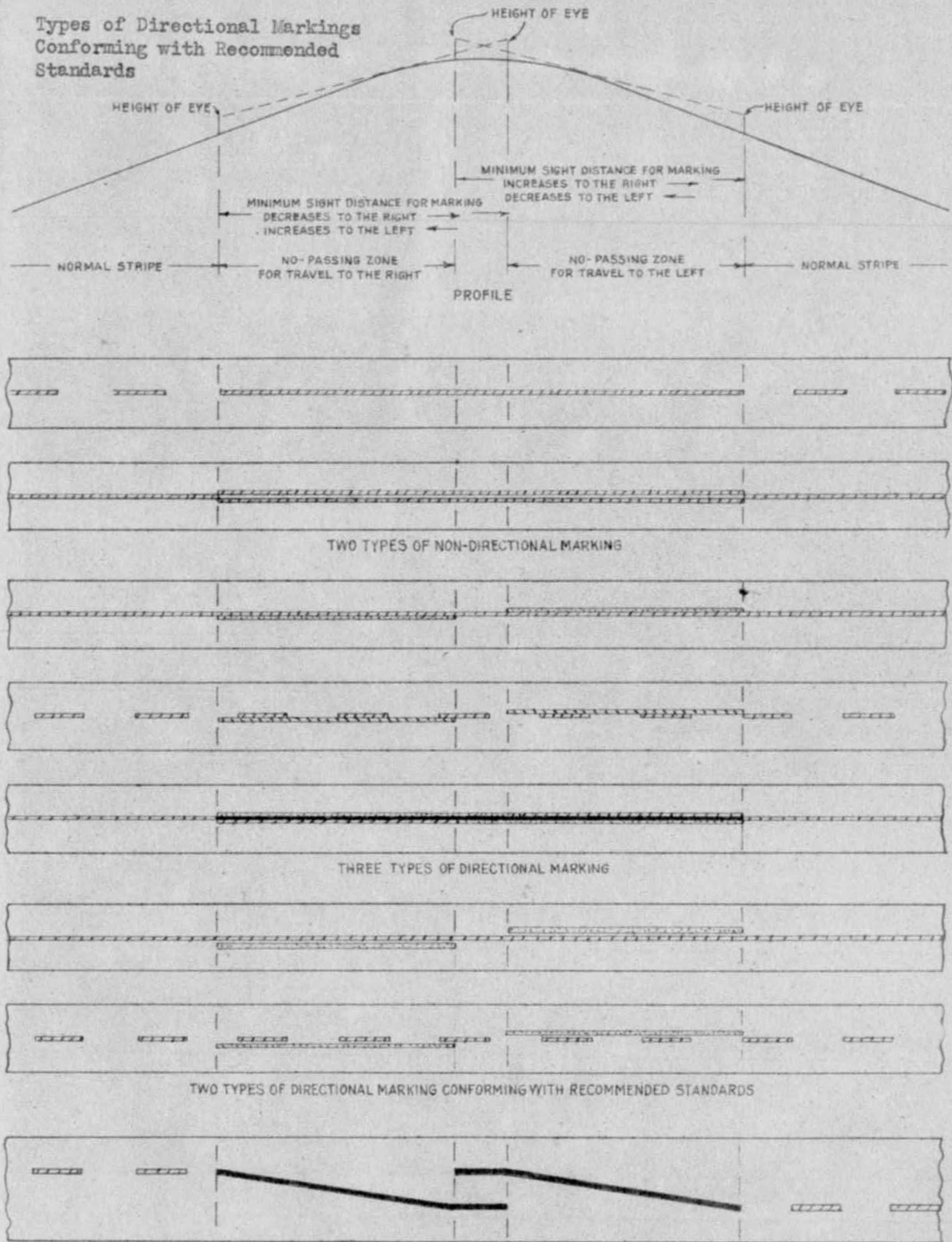
Where a considerable density of left turning traffic is expected, it is often desirable to omit the restrictive stripe and mark the middle lane on the approaches to an intersection for the exclusive use of left turning vehicles.

Standards for Marking and Signing No-Passing Zones

The following are standards for marking and signing no-passing zones

FIGURE 7

Types of Directional Markings Conforming with Recommended Standards



DIRECTIONAL MARKING ~ THREE LANE

as adopted by the Special Committee on Administrative Design Policies (U. S. Public Roads Administration):

1. No-passing zones for traffic in either direction on a highway, as defined by the Special Committee on Administrative Design Policies, shall be marked by an auxiliary or barrier stripe placed to the right of the normal centerline, i. e., in the lane of traffic that it is to govern.

2. The barrier stripe shall be a solid yellow line. In order that the barrier line shall be distinctive, the normal centerline shall be either white or black. It may be of solid or broken type.

3. The barrier line shall not be narrower than the normal centerline, nor in any case less than 4 inches wide. It should preferably be at least 6 inches wide.

4. The barrier line shall be separated from the normal centerline by a distance equal to half the width of the centerline.

5. The combination no-passing stripe shall be identical as applied to both two-lane and three-lane roads.

6. On a two-lane road the no-passing marking shall separate the two lanes throughout the no-passing zone. On a three-lane road the combination no-passing stripe shall start from the left-hand lane marking line and extend at an angle of not less than 20 to 1 across the center lane to meet the right-hand lane line at the beginning of the no-passing zone, and thence will extend along the lane line to the end of the zone.

7. The same design of no-passing stripe shall be used for all types of no-passing restrictions.

8. The use of signs in addition to the above specified markings to designate no-passing zones shall be governed by local legal requirements or

otherwise, at the option of the State, but when signs are used they shall conform to the specifications set forth in the Manual on Uniform Traffic Control Devices for Streets and Highways.

Highway Channelization

There are numerous hazards in past highway construction that cannot be solved completely by the use of "Striping". These hazards, again, are normally on hills and curves and as usual receive their hazardous reputation from the inclination of the drivers to pass the leading car where sight distance is limited.

Several solutions have been attempted, such as installation of reflectorizing buttons, rubber flaps, and medial dividers. Reflectorizing buttons, used because of their distinct advantage to night driving, have the added effect of a slight bump when the car crosses them. Rubber flaps have the same effect, and in addition, further call the attention to the driver of his position by the slapping noise caused by the tires crossing them.

Both of these practices are better adapted to use on curves than on hills. Both warn any driver who unconsciously allows his wheels to edge over ther centerline; but they cannot be expected to prevent any illegal passing if the driver desires to make an attempt.

The medial divider therefore becomes the next choice where all other attempts to halt illegal passing have occurred. The ideal medial divider is such a one which would be difficult but not impossible to cross. It would be so designed that should an emergency warrant a driver could cross over without fear of personal injury or injury to his vehicle. Although numerous experiments have been made in the attempt to develop such a medial divider as would fit this description, none has met the approval of the driving public.

However, channelizing traffic to its own lane in order to eliminate medial accidents or friction at hazardous points is often necessary. In channelizing pavement by use of a medial divider certain other conditions of the road are altered and must be corrected.

Obviously, the shoulders of a channelized two-lane pavement must be constructed wide enough and firm enough to permit a car to move completely off the pavement if it is forced to stop within the channelized portion of the highway. This is necessary to prevent the complete blocking of all traffic in one direction in case of the breakdown of a vehicle where the lanes are separated. To provide the necessary width, the shoulder should be at least six feet wide on each side of the road. A width of eight feet is considered much better, since it permits drivers to move their cars completely off the pavement, without being dangerously close to the edge of the shoulder. Where guard rail is used, the shoulder should be made wide enough to provide from six to eight feet between the guard rail and the pavement edge. The shoulders of a channelized two-lane highway should be so constructed and so maintained that, in any weather, a driver will not be afraid to trust the shoulder with the weight of his car. If the shoulders are to serve their purpose at all times, they must be kept free of snow.

Where funds are available for the necessary construction work, the passing and congestion problem can both be better solved together, through widening of the pavement to four lanes on the hazardous hill or curve. In this construction if the pavement is merely widened without the addition of a medial divider, the temptation and necessity to cross the centerline will be greatly reduced, but such a dangerous move will still be possible. This type of widening, preventing congestion caused by slow moving trucks, will materially reduce the number of medial accidents, although it cannot eliminate this type of accident entirely.

In order to eliminate completely both congestion and medial accidents, construction of a four-lane pavement through the hazardous location is necessary. In this construction the double lanes in each direction must be separated by a medial divider which cannot be crossed. Such construction will probably never be feasible for promotion unless it is anticipated that the entire road will later be widened to four lanes.

Design of the Medial Divider

Medial dividers in use today are of various types and sizes. It has, however, been found desirable where the entire two-lane highway is being newly built, to construct a concrete divider with sloping sides or to install a planted strip in the center of the road. Where the divider is to be installed in a pavement already in place, it should be such that it can be placed without making removal of excessive pavement necessary. Nor should it be such that excessive pavement widening is necessary to make up for the width occupied by the divider. Normally the divider can be effectively designed to occupy two feet of width on a four-lane highway and one foot of width on a two-lane highway. In considering the divider design it must be remember that it should be of such construction as to stop any car striking it and to turn it back into its own lane without damage to the car.

A divider, intended to meet these requirements, was recently designed and tested by the Bureau of Street Traffic Research of Yale University, working in conjunction with the Michigan State Highway Department. This divider, as installed, was made of steel and withstood successfully some rather severe tests when it was tried out on a stretch of abandoned concrete pavement in Michigan. Automobiles, of sizes ranging from the lightest passenger cars up to seven-ton trucks, were driven against the divider at speeds ranging up to 60 miles per hour. These tests were made in both wet weather and in dry weather. In every case the vehicle was thrown back into its proper lane without being damaged and without being thrown out of the driver's control.

Such a divider, for use on two lane pavements, requires that the construction at the ends be designed to satisfy the following requirements:

1. The divider should be visible at least 1,000 feet away in either daylight or dark. The intensity of the car lights, or course, are to be considered in night driving. If the divider cannot be seen at the 1,000 foot distance, it is entirely possible and probable that someone, in the process of a passing maneuver at high speed, will find himself on the wrong side of the divider and in the path of the descending traffic.

2. Should a car strike the divider head on, the construction of the divider should be such that the car will not be thrown out of control, but rather guided toward the proper lane and slowed until the driver can assume full control.

Where narrow dividers are used on two-lane highways, difficulty is encountered in obtaining the above requirements without construction of islands at each end. The islands may be planted with shrubbery of suitable size and toughness to withstand and relieve the shock of car, or the island may be concrete, shaped so that if a car strikes it, it will be gradually slowed or deflected into the right hand lane. In either case, night visibility may be obtained by use of relectors or flood lights.

Location of the Medial Divider

The proper length for the divider is a debatable subject, and no definite criteria have been established on this. However, in designing the divider, the following matters in relation to its length should be considered: A length of 1,000 feet, measured down hill from the point at which a car can first be seen to come over the crest from 2,000 feet away, will prevent all medial accidents that are caused by short sight distance. This length may be reduced to 600 feet without endangering anybody who is not passing a car that is moving at least 30 miles per hour. The length of 1,000 feet down each slope will make the highway as nearly "foolproof" as any two-lane highway can be made, but a 600-foot length down each slope will probably make the hill almost equally safe. The shorter divider will also reduce the cost of construction, the amount of congestion, and the delay on the hill.

The channelization of a two-lane highway should be considered only where there is plenty of straight road, with long sight distances, at each end of the proposed channelization. On roads where hills and curves are close together, and where paint lines have not proved satisfactory in preventing accidents, the best engineering measure is widening to four lanes in the most dangerous places.

Elevating Curbs

One of the newest advents in highway design to meet the ever changing needs of traffic in volume is the design of the elevating curbs. No figures are available with which to compare the construction and maintenance costs of this against other practices, as the first test of this installation is at the present time being made. The 2.2 miles of the new North and South through-road in Lincolcn Park, Chicago, has been chosen for this test.

The purpose of this installation and factors bringing this about are discussed below:

The Traffic Problem - New designs in any highway construction are usually the result of a new traffic problem - a case where necessity is the mother of invention. As it happened in this case, the design needed was such a one as would successfully combat the problem of segregating unbalanced two-way traffic in enormous volume.

After a careful study of the traffic, records such as that shown on Table II were obtained. This table shows a comparison in the direction of travel for the various important periods of the day, the volume of the movement as a percent of the 24 hours total traffic.

These records indicated that six lanes would carry the heaviest rush-period traffic flows, whether south in the morning or north in the evening, and that two lanes would carry the counter-traffic flow of either north or south. Also it was indicated that four lanes each way would meet all non-rush-hour traffic demands.

Assuming that physical separation of opposing streams of traffic was essential, two design possibilities existed: (1) a divided highway each half of which would carry the heaviest rush-hour travel or (2) some form of highway that could be converted by movable separating strips of two and six or four and four lanes in either direction. The second possibility was selected for first consideration.

In Table II it will be noted that the six hours of the rush periods contributed 40.8 percent of the total 24 hour traffic. Of this traffic, 32.3 percent operates in the prevailing rush direction and 8.5 percent operates in the counter-rush direction. With a normal fixed separating strip, six lanes in each direction, or twelve lanes, would be necessary to provide capacity. These lanes would have required 148.33 feet of pavement and 21.66 feet of center parkway or a total of 170 feet. The 21.66 feet of parkway is necessary to give scale and proper landscape character to 148.33 feet of pavement traversing a park. In contrast, with movable separating strips, eight lanes (100 feet) were adequate and offered a possible saving. In the Lincoln Park operation the cost of 70 feet extra width offset the cost of the elevating curbs by more than two to one.

The problem was the movable separating strips. It was solved by devising, after many tests, an elevating curb - a curb 19 inches wide, that could at will be elevated 8 inches above the pavement or lowered flush with pavement level. Three lines of curbs were designed, one along the center of the eight-lane roadway and one two lanes away on each side of the center curb. Each line of curb retracts into an underpavement slot that contains the hydraulic jacks, springs, piping, electrical wiring, etc.

Only one line of curb designed to be raised at a time in the normal operation of the road, the curbs being operated by a hydraulic fluid and gas, controlled by switches from the control boxes located at the extremities of the system.

Only one line of curb at a time is raised in the normal operation of the road. The location of the up-curb depends on the density and direction of traffic during the various periods of the day. (See Table II.) In the morning rush hours when the traffic is directional to the business district, the east line of curb is raised, thereby separating the roadway into six lanes for southbond traffic and two lanes for northbound traffic. In the evening rush period when the prevailing traffic is directionally away from the business district, the west line of curb is raised, thereby separating the roadway into six lanes for northbound traffic and two lanes for southbound traffic. During the periods between the morning and evening rush hours, which may be termed the normal periods, due to the even balance of flows, the centerline of curb is raised to separate the roadway into equal parts.

This construction, as mentioned before, is new in the highway field. Its advantages in particular sections of city traffic where that traffic requires segregation of unbalanced two-way traffic, are easy to understand. Its uses, however, are limited to city or inter-urban traffic because of the cost of maintenance and construction.

Such a development as this does tend to bring out the importance of research and proper highway planning by properly qualified engineers and to show that highway construction and design is still in its infancy.

TABLE II

NORTH AND SOUTH TRAFFIC VOLUME AT DIFFERENT PERIODS OF THE DAY THAT WILL USE THE LINCOLN PARK THROUGH ROAD, CHICAGO.

Period	Curb Arrangement	Length of Period Hours	Direction of Travel Percent N	S	Movement Percent of 24-hour Vols. N	S
Morning Rush 6:30 - 9:30 AM	6 lanes S 2 lanes N	3 hrs.	17.7	82.3	3.2	15.1
Daylight Normal 9:30 AM - 4 PM	4 lanes S 4 lanes N	6.5 hrs.	46.7	53.3	13.1	15.0
Evening Rush 4:00 - 7:00 PM	2 lanes S 6 lanes N	3 hrs.	76.3	23.7	17.2	5.3

CHAPTER VI

DETERMINING RELATIVE NEED FOR WIDENING PAVEMENTS BEYOND TWO LANES

One of the most important highway problems is presented when reconstruction of a highway is necessitated by traffic volume increases. The determination of a program of future improvement or selection of projects for widening requires a studied consideration of all the factors involved, but it is important that special attention be given to the number of vehicles that will be benefited by particular improvements. Generally, widening programs have heretofore been based on judgment and perhaps reinforced by figures of total or average traffic on an annual basis. Now that means are available for automatically recording the traffic volume at hourly intervals, extensive widening or realignment programs need not be undertaken without a more exact knowledge of the gains derived by the public from each project.

It is logical that the number of vehicles benefiting from an improvement designed to relieve congestion will depend on the annual traffic volume, although in a great many instances the fluctuation of the traffic flow may produce a greater influence on the intended benefit than will the volume itself. Little benefit to vehicles normally moving in light traffic will be provided by adding an additional lane. It is reasonable then to assume that these vehicles should <u>not</u> be included in that total number to be affected by the improvement. The decision as to the number of lanes required on any certain highway, or the priority of individual projects in any program of improvement should therefore be based on the number of vehicles moving in periods of heavy traffic rather than on figures of annual average 24 hour traffic only.

Preliminary results of highway capacity studies conducted by the Public Roads Administration on level tangents in several of the States have revealed that as the density of traffic on a highway increases, the freedom of movement decreases at a nearly constant rate. Because there is no sudden change in the freedom of traffic flow with increasing density, there is no particular point at which the road must be widened. But, rather, the opportunity for individual choice of speed is gradually reduced until each driver must govern his speed by that of the vehicles preceding him, regardless of his own wishes.

Various indices have been developed to measure traffic congestion, the most sensitive being that shown in Figure 8 (Curve B). Upon observation of this figure, it is evident that as the spacing between vehicles decreases there is little change in the difference in speed of successive vehicles until the time spacing is reduced to nine seconds. Below this spacing the speed of the following vehicle approaches that of the one ahead rapidly, thus indicating that with a spacing of nine seconds, drivers are affected by the presence of the car ahead and that the shorter these spaces become the greater is the effect. Should all vehicles using the highway be equally spaced, the determination of the point of incipient congestion would be a simple matter. However, it is a well known fact that vehicles do not move with uniform separating intervals, but rather, tend to group. This tendency to form groups is very common to highway traffic. Under practically any conditions of speed and traffic volume, approximately two-thirds of the vehicles will be spaced at, or less than, the average distance between vehicles. Using this average curve of vehicle spacing, it is evident that with an hourly volume of 180 vehicles in one direction (representing an average spacing of

20 seconds) about 120 vehicles will be 20 seconds or less behind the car ahead, and of these 120, fully one-half will be spaced at nine seconds or less and will therefore be affected to some degree by the car ahead. As traffic volume increases, the number so spaced increases. With 200 vehicles an hour in one hour, 52 percent will feel some effects of congestion; with 300 vehicles per hour, the figure becomes 60 percent; with 400 it becomes 70 percent, and so on until over 90 percent of the vehicles are affected when the volume becomes 1,000 vehicles per hour in each direction. The extent to which a road may be allowed to become congested before steps are taken to widen or otherwise to increase its capacity will naturally depend on the availability of funds for such work. States with adequate funds might decide that when half of the vehicles feel the effect of congestion, the time has arrived for widening. Other States with less adequate funds might of a necessity set the figure higher. However, it is considered that a figure of 70 percent is an absolute limit, which then sets a figure of 400 vehicles per hour in one direction, or 800 in both, as the maximum traffic volume that a two-lane road of the best alignment and grade may be expected to carry without intolerable congestion.

Other indices of traffic congestion substantiate this figure. In light traffic nearly any desired speed may be maintained, but as the volume increases,the freedom of choice becomes restricted. The resulting increase in congestion may thus be measured by the decrease in the average speed difference between successive vehicles. From an average difference of 6.5 miles per hour in very light volume, this figure drops to 4.0 on typical two-lane tangents at a volume of 800 vehicles per hour in both directions. Although again this is but a relative figure, it is reasonable to belive that it represents a maximum desirable figure when it is considered that for corresponding speed differences four-lane roads accommodate from 2,000 to more than 4,000 vehicles per hour.

Another index is the measure of the opportunity for vehicles to pass other vehicles moving in the same direction. If it is assumed that the alignment of the highway itself is not a factor, passing is limited only by the time the opposing lane is occupied. Analysis of the normal spacings of vehicles with various traffic volumes shows that with opposing volumes of 400 vehicles per hour, passings requiring ten seconds can be started during less than 30 percent of the time. In other words, in less than one out of every three times can such a passing be started without trailing the car ahead for some distance. With decreasing volume of opposing traffic, opportunity for passing increases rapidly. With hourly volumes of above 400, the opportunity decreases but at a slower rate.

The figure of 800 vehicles per hour refers to two-lane roads of the best alignment, on which the sight distance is never less than 1,000 feet. Frequent recurrence of shorter sight distances tends to reduce the volume of traffic which a road will carry without undue interference, by decreasing the relative number of places along the highway where passing maneuvers can be safely started. The exact relation between the alignment and permissible volume at peak periods cannot be determined before the programmed studies are completed, but a consideration of the available data regarding passing distances indicates that volumes as low as 400 vehicles per hour (both directions included) will seriously interfere with the freedom of movement and cause very undesirable conditions on sections with poor alignment or where the sight distance does not exceed 1,000 feet for at least 50 percent of the time. In

SPEED CHARACTERISTICS OF VEHICLES TRAVELING AT GIVEN TIME SPACINGS BEHIND PRECEDING VEHICLES

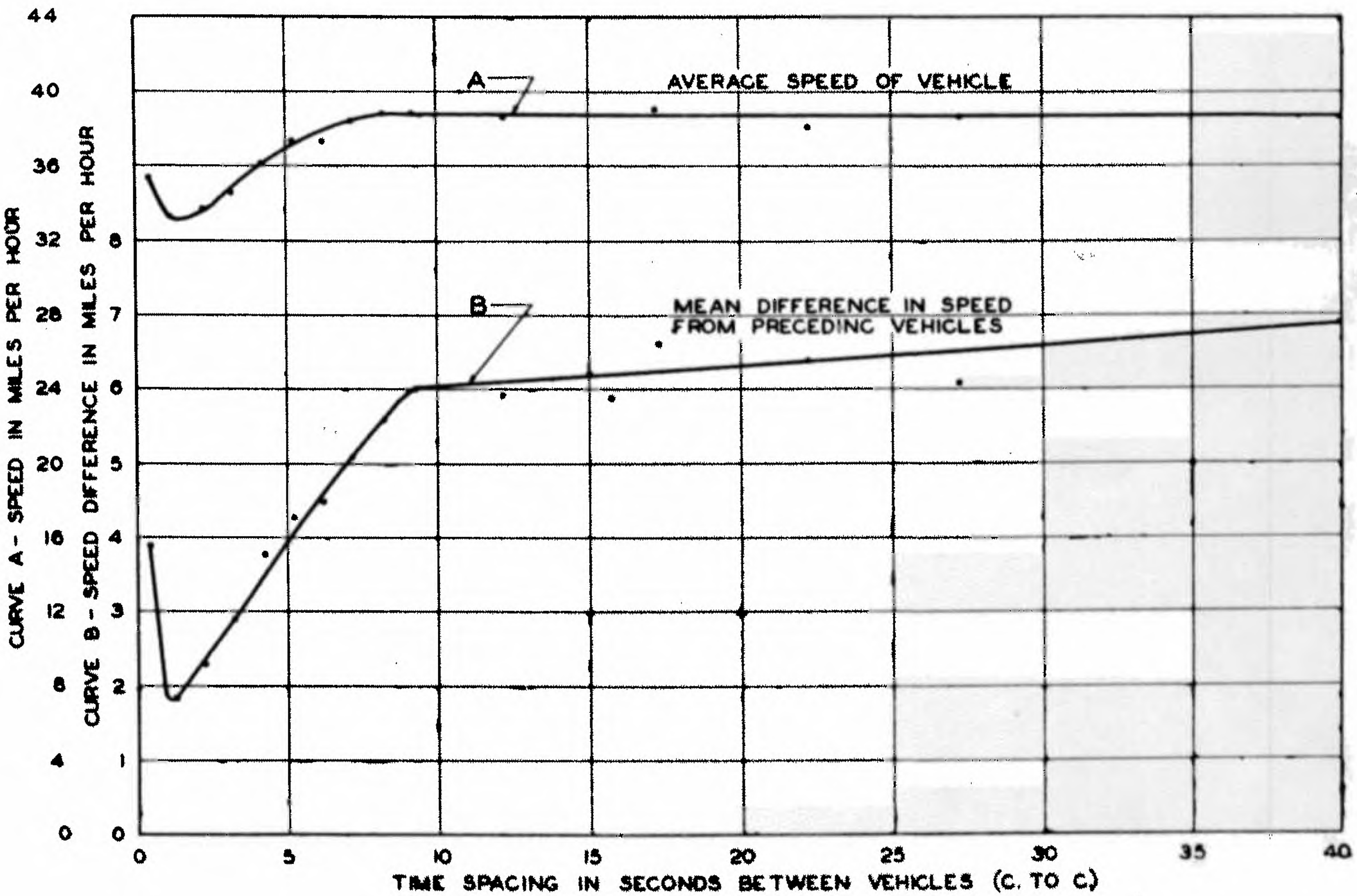


FIGURE 8

determining an appropriate congestion figure for a particular road, alignment and sight distance must be carefully studied.

To compare projects, by these methods, for the determination of priority of widening, it is necessary to find the number of vehicles moving over each proposed project during periods of congestion. The usual figures of average or total traffic are not useful for this purpose. It becomes necessary to translate such average or total figures for traffic volume into figures showing the numbers of vehicles traveling in periods of congestion by means of factors derived from available pertinent traffic patterns, or to determine these figures by the use of automatic records if detailed traffic patterns are not available. Moreover, it is necessary to estimate on the basis of the present traffic figures determined for each project the corresponding volumes of probable future traffic resulting from assumed reasonable rates of increase. For the purpose of determining priorty of projects, nearly any reasonable figure for allowable congestion may be used, but in deciding whether more than two lanes must be provided, care must be used in the selection of this value, and a proper balance must be drawn between the desirable improvements and the availability of funds.

Various studies by the Public Roads Administration indicate that no general rules may be applied to determine, from the average traffic volume, the extent of congestion on any given road. The studies of this group do show, however, that on any roads, except possibly some few whose entire alignment consists of level tangent, there is a possibility of congestion wherever the average volume exceeds 2,000 vehicles per day. Therefore, before the designation of any projects for widening beyond two lanes, an analysis should be made of the traffic characteristics on all roads within the state on which the average volume equals or exceeds this figure (2,000). Traffic on any road thus indicated as now congested to any appreciable extent, or as likely to be in the near future, should then be carefully analyzed by means of a full year's record of an automatic counter located on that road, utilizing either a permanent installation, or a portable recorder, operated on an approved schedule. The cost of such preliminary traffic analysis is all but insignificant in comparison with the normal costs of locating and designing modern widened highways. Now that equipment and technique permit it, improvement programs may be based on an intelligent determination of the needs of the traffic.

The following study made by the Public Roads Administration, of two Maryland road sections on which automatic traffic recorders were operated, illustrates the procedure for determining when the surface of a road section should be widened beyond two lanes and when other measures should be taken to increase road capacity, and for establishing priorities for such work.

The section on US 40 between Hagerstown and Huyett (hereafter called Section A) and the section of State Route 4 from Upper Marlboro to Hills Bridge over the Patuxent River (hereafter called Section B) have seasonal traffic characteristics as shown by the following table. In making the four groups from the twelve months, the three months with the lowest traffic volume are placed in the first group, the three months of the remaining nine with the lowest traffic volume are placed in the second group, etc.

Period	Section A Total Traffic Vehicles	Section A Total Traffic Percent	Section B Total Traffic Vehicles	Section B Total Traffic Percent
December) January) February)	199,461	18.1	136,272	12.6
November) March) April)	232,897	21.1	173,917	16.1
September) October) May)	300,744	27.3	269,520	24.9
June) July) August)	369,369	33.5	501,667	46.4
Total	1,102,471	100.0	1,081,376	100.0
Average Daily	3,020		2,963	

The week patterns of the two sections are as follows:

Day of Week	Section A Average Daily Traffic Vehicles	Section A Average Daily Traffic Percent	Section B Average Daily Traffic Vehicles	Section B Average Daily Traffic Percent
Sunday & Holidays	4,140	19.8	6,167	30.4
Monday	2,558	12.2	2,024	10.0
Tuesday	2,589	12.4	2,017	9.9
Wednesday	2,664	12.7	2,113	10.5
Thursday	2,721	12.0	2,057	10.2
Friday	2,834	13.5	2,180	10.8
Saturday	3,431	16.4	3,678	18.2

These two road sections carry very nearly the same number of vehicles per year, the average daily traffice being 3,020 on US 40 (Section A) and 2,963 on State Route 4 (Section B). The seasonal and weekly traffic characteristics are, however, quite different. On Section A about 18 percent of the annual traffic occurs in December, January and February, and about 33 percent occurs in June, July and August. On Section B, however, less than 13 percent of the annual traffic occurs in December, January and February, and more than 46 percent of it occurs in June, July and August. The variation in the annual pattern is graphically illustrated by figure 9.

The variation in the weekly pattern may be of even greater importance than the difference in the seasonal graph. In the illustration cited above the weekly variation is of great importance because a major part of the traffic on Section B is carried on Sundays and holidays, whereas the traffic on Section A is more evenly distributed.

The following table shows in a condensed form the percentage of the total number of hours in the year during which each of these road sections carries traffic in excess of stated numbers of vehicles per hour.

Hourly Volume (Vehicles)	Section A Percent of Total Time	Section B Percent of Total Time
1,300 and over	0.00	0.00
1,200 and over	0.00	0.07
1,100 and over	0.00	0.17
1,000 and over	0.00	0.33
900 and over	0.00	0.71
800 and over	0.00	1.14
700 and over	0.01	1.74
600 and over	0.06	2.35
500 and over	0.23	3.39
400 and over	1.27	4.90
300 and over	4.10	8.29
200 and over	15.59	15.80
100 and over	60.11	40.00

On section A the traffic is rarely in excess of 700 vehicles per hour, whereas on Section B it is sometimes in excess of 1,200 vehicles per hour, and is in excess of 800 vehicles per hour over one percent of the time.

It is obvious that the percentage of vehicles passing when the hourly traffic volume is great will be much higher than the percent of time during which the same high hourly traffic volume continues. The following table shows the percentage of all vehicles passing over each of the road sections referred to above during a year, when the hourly traffic volume was in excess of the specified number of vehicles per hour:

Hourly Volume (Vehicles)	Section A Percent of Total Vehicles	Section B Percent of Total Vehicles
1,300 and over	0.00	0.00
1,200 and over	0.00	0.69
1,100 and over	0.00	1.64
1,000 and over	0.00	2.99
900 and over	0.00	5.88
800 and over	0.00	8.50
700 and over	0.06	12.43
600 and over	0.30	15.63
500 and over	1.01	20.24
400 and over	4.60	25.67
300 and over	12.29	35.15
200 and over	34.04	50.05
100 and over	84.21	78.43

On Section A, one percent of the vehicles are traveling when the hourly traffic volume is 500 vehicles or more. On Section B, on the other hand, more than 20 percent of the vehicles, or about 200,000 per year, are traveling when the hourly traffic volume is 500 vehicles or more, and more than 8 percent, or about 80,000 per year, are traveling when the hourly traffic volume is 800 vehicles or more.

It can be seen that on Section A the hourly traffic volume is never as great as 800 vehicles per hour, which is the figure given above as the point at which freedom of movement is seriously affected on routes having ample sight distance throughout. As sight distance conditions are excellent on this particular road section, congestion is not serious.

Section B presents a different problem. On this section, which is

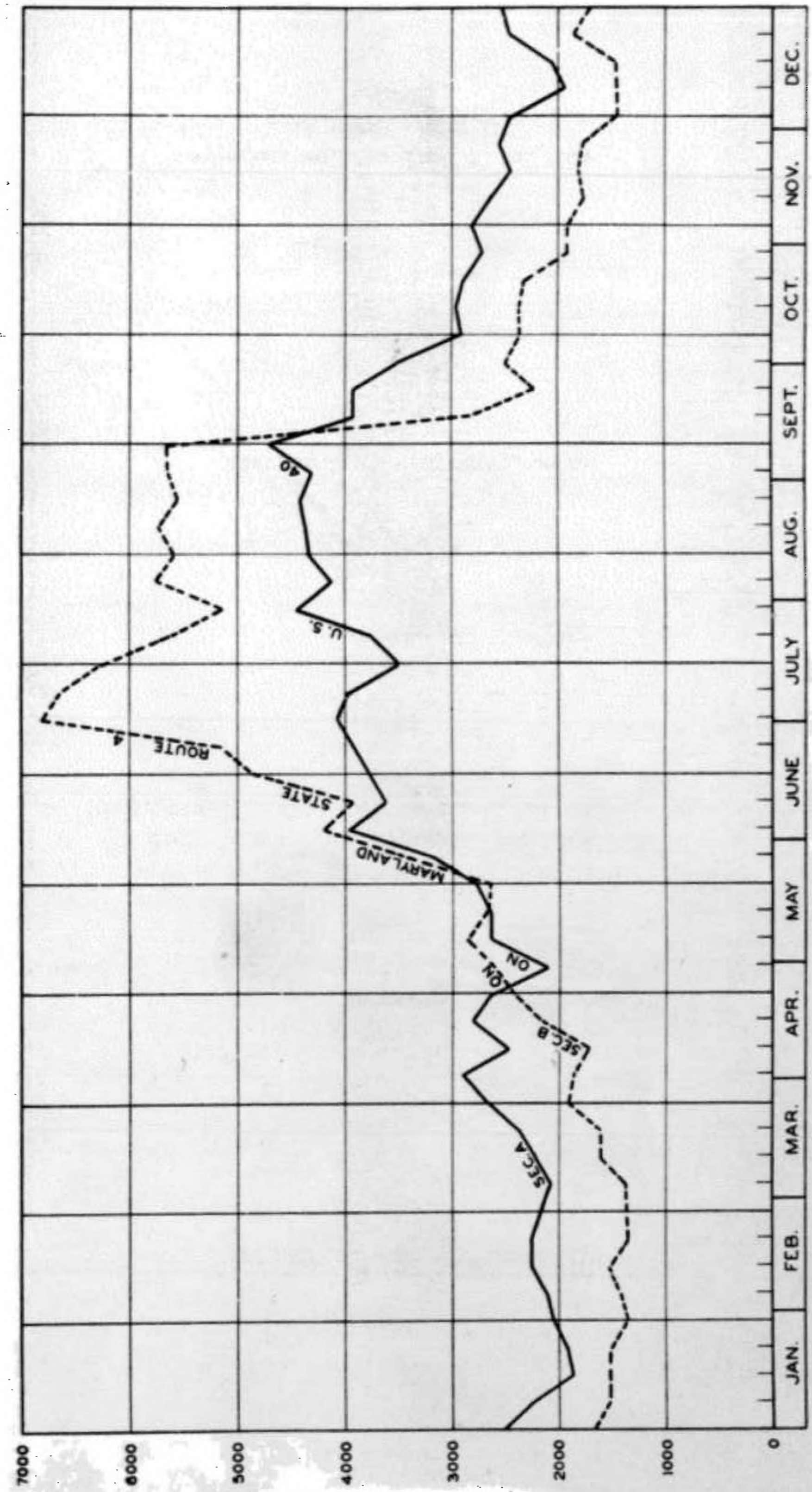
1.9 miles long, there are 9 points at which the sight distance is less than 1,000 feet, and at 6 of these points the sight distance is less than 500 feet. Under such conditions, traffic is unduly restricted when the hourly traffic volume is in excess of 500 vehicles per hour, yet more than 20 percent of the vehicles using this road section are traveling when such a condition exists. Even if the sight distance conditions were completely corrected, an appreciable number of vehicles would be traveling at a time when there is undue restriction of movement, because more than 8 percent of them are on the road at a time when the hourly traffic volume is 800 vehicles or more.

A study of the future traffic characteristics of a road can usually be based on the present traffic pattern. When a traffic pattern has been determined, it will generally be safe to assume that this pattern will not change materially with either an increase or a decrease of average daily traffic. Assuming that a point of saturation has not been reached, any increase or decrease in the total volume of traffic will, in general, affect all portions of the traffic pattern proportionately. In applying this principle, however, it will be necessary to consider the possibility of future local developments tending to influence the pattern.

If it is assumed that the form of the traffic pattern will not be affected by increase of total traffic, an estimate of the time when corrective measures should be taken to increase the road capacity can be made by using data similar to that presented above. The average trend of traffic on the type of highway under consideration will indicate the probable total traffic or average daily traffic in three years, five years, or in other desirable and reasonable predictable periods of time. A series of curves can then be

FIGURE 9 NUMBER OF VEHICLES

(Average Daily Traffic)



Seasonal Fluctuation in Traffic Volume

plotted, using the percent of total time or percent of total vehicles as ordinates and the hourly volume of vehicles as abscissas and the present pattern as a base curve. Similar curves can then be drawn, assuming that the hourly volume will expand in proportion to the total daily or annual traffic. Thus, if 5 percent of the total traffic passes over the road when the hourly volume is 400 vehicles per hour or more, it is probable that if the total traffic is increased 25 percent, approximately 5 percent of the total number will pass over the road when the hourly traffic volume is 500.

Figure 10 is plotted to show, for Section A, the percent of vehicles traveling when hourly volumes are of different magnitudes, assuming that traffic has been increased 25 percent, 50 percent, 75 percent and 100 percent. With average daily traffic figures of 3,775; 4,530; 5,285 and 6,040 vehicles, corresponding to the increases mentioned, the percentages will be as follows:

		Percent of Total Vehicles with Estimated Average Daily Traffic			
Hourly Volume (Vehicles)	Percent of Total Vehicles (Average Traffic 3,020)	Increase 25 Percent (Average Traffic 3,775)	Increase 50 Percent (Average Traffic 4,530)	Increase 75 Percent (Average Traffic 5,285)	Increase 100 Percent (Average Traffic 6,040)
1,300 and over	0.0	0.0	0.0	0.0	0.2
1,200 and over	0.0	0.0	0.0	0.1	0.4
1,100 and over	0.0	0.0	0.1	0.2	0.7
1,000 and over	0.0	0.0	0.2	0.4	1.0
900 and over	0.0	0.0	0.4	0.9	2.0
800 and over	0.0	0.2	0.9	1.7	4.6
700 and over	0.1	0.5	1.8	4.6	7.2
600 and over	0.3	1.2	4.6	7.5	12.3
500 and over	1.0	4.2	8.5	13.3	19.0
400 and over	4.6	10.0	16.1	24.3	33.7
300 and over	12.3	22.5	34.6	51.7	66.0
200 and over	34.0	59.7	73.4	80.0	84.4
100 and over	84.2	89.0	91.7	94.2	95.8

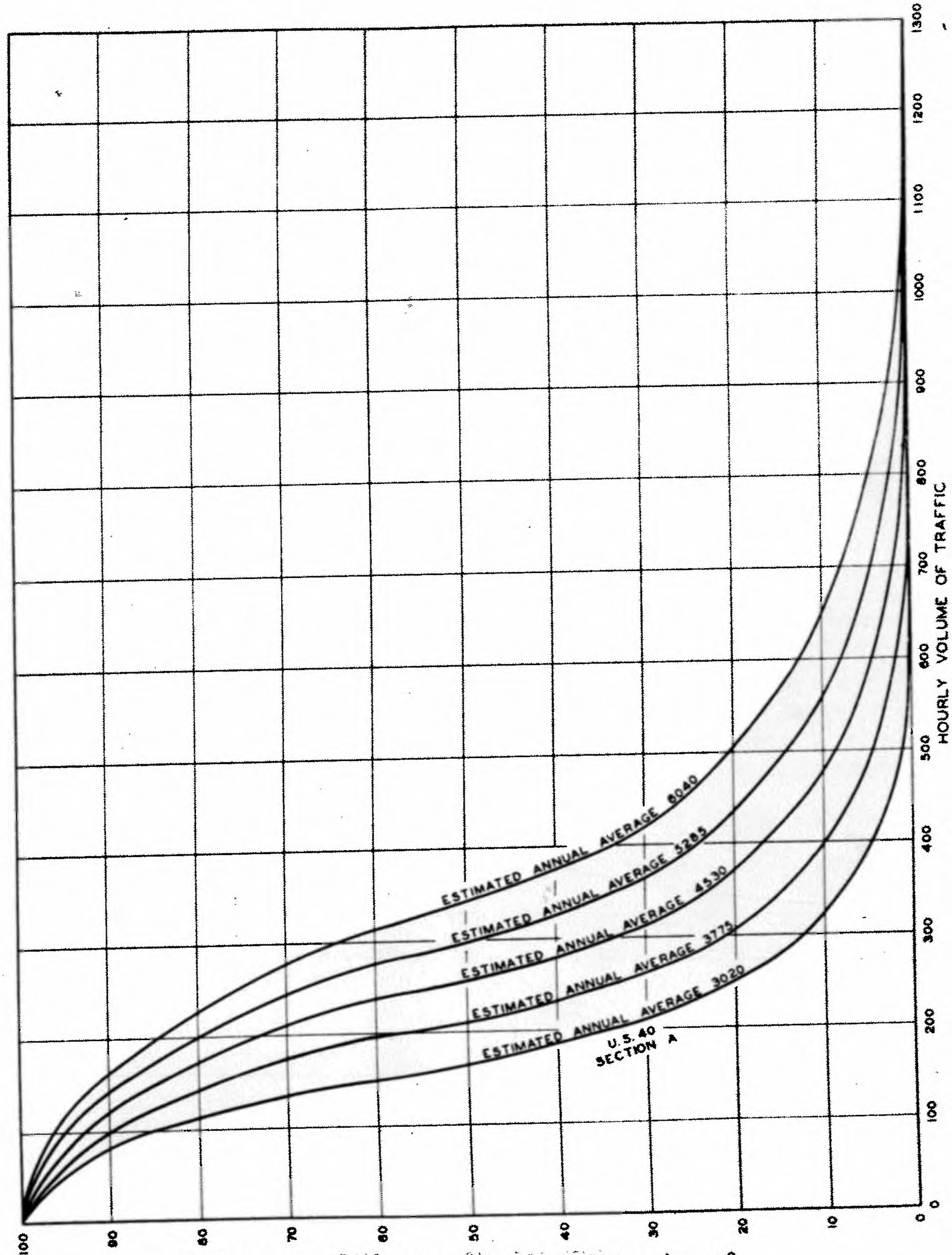
From the curves in figure 10 and the data given above, it is clear that if the traffic increases 25 percent, the volume will occasionally be greater than 800 vehicles per hour. If it increases much more than this, congestion will undoubtedly be serious and widening beyond two lanes will be required, even though the alignment and grades are excellent.

Percentage increases of any amount can be plotted on the curve by shifting a series of points on the original curve horizontally to the right an amount proportionate to the increase in traffic and drawing the curve for estimated traffic through these points. For example, if it is desired to determine whether more than two lanes will be required in 1945, and if it is estimated that the traffic will increase 37 percent by that time, a curve may be added for average daily traffic of 4,137 vehicles. The curve would be drawn by shifting the percentage of total vehicles at the various points of hourly volume to the right by 37 percent. Thus, while 84.2 percent of the total traffic now uses the road when it is carrying 100 or more vehicles per hour, there will be, by 1945, if the traffic increases as assumed, 84.2 percent of the total traffic using the road when it is carrying 137 or more vehicles per hour. Other points would be shifted in a similar manner to form the complete curve. The various percentages of traffic using the road at the hourly traffic volume points of 100, 200, 300, 400, etc., are read from the curve for the estimated traffic.

From the percentage figures, a calculation may be made to show the actual number of vehicles using the road when the traffic volume is in excess of 400, 500, 800, or whatever number of vehicles per hour has been predetermined as the maximum volume of traffic which can move without undue interference over the section being studied. Presumably, the road carrying the greatest number of vehicles during periods when the hourly figure is in excess of the standard set will be given first priority if other conditions are equal.

FIGURE 10

PERCENT OF TOTAL VEHICLES



Vehicles Traveling When Hourly Volumes Are of Different Magnitudes

CHAPTER VII

THE USE AND APPLICATION OF ENLARGED TRAFFIC SIGNS

During recent months the general public and especially the highway engineer has been hearing a great deal about the highways of tomorrow and what might be expected when our magnificent system of superroads becomes a reality. It is the general opinion of highway engineers that eventually each class of highways, from the heavily traveled high velocity highway to the little used feeder road, must be properly and adequately planned and improved in order that we may have a more unified, safe and economical roadway system.

It is apparent that time and the expenditures of vast sums of money stand in the way of this as an immediate goal to be reached.

The use of striping and medial dividers, which has been discussed just prior to this, would not have any use on the highway systems of this day if relocation or redesign could economically be substituted. Because relocation or reconstruction cannot, in a great many cases, be used to eliminate the hazards from the highways, it becomes necessary to adopt the next best principle, consisting of striping, placement of medial dividers, or placement of signs.

Until 1929 no great thought was given to the proper and uniform methods of signing the highways. At this time the American Association of State Highway Officials and the American Engineering Council, cooperating, named a joint committee whose duty it was to make specific recommendations on uniform traffic control devices for streets and highways.

The result of the concerted action of these two groups has been evident in the splendid improvement in all types of signs and markings. Color combinations, shape, stroke of letter or symbol, and spacing have all been given thorough consideration and recommendation for standardization by the joint committee.

This same committee in its manual on Uniform Traffic Control Devices issued in 1937 clearly makes the following statements: [1] "With the exception of route markers and illuminated signs mounted on signal standards, they shall have an outside minimum dimension of at least 24 inches. Where conditions require greater visibility, necessitating a larger sign, the outside dimensions shall be in multiples of 6 inches". Again this manual states: [2] "Signs for use on high-speed highways should be considerably enlarged - to the size of billborads if necessary". This latter statement or provision in this manual provides sufficient official leeway in construction of the enlarged sign so that under certain conditions where there is primary need for signing, such a sign as will "demand" the attention of the motorist may be considered as meeting the proper size standards of signs.

Sign Classification

There are three classifications of signs to be considered when dealing with the enlarging of signs, namely (1) regulatory, (2) warning, and (3) guide. By far the greater number of super signs would certainly be included under the latter two, although there is certainly definite need for enlarged regulatory markers at entrances to populated centers, heavily laden intersections, etc.

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[1] Page 23, Section 128, Dimensions.
[2] Page 29, Section 141.

Signs, both large and small, if properly placed, should constitute an aid which the normal driver requires for the safe operation of his vehicle. The driver in turn must consider the sign as an added effort to control the traffic more effectively and to lessen accident possibilities.

Sign failures would probably be of no significance if it were not for the fact that sign placements are always at hazardous spots. The present day driving speeds allow little time and certainly no speculation time on what the sign may mean. On the contrary, as is the case of the stop sign, the meaning of the sign must be transmitted immediately to the driver's mind at a single glance, without distracting his attention from the road or traffic ahead long enough to alter the path of his car or to prevent him from doing whatever is necessary to avoid an accident.

SLOW SIGNS, one of the principals of the warning series of signs, have been used so carelessly that they are now in high disfavor among the traveling public. For numerous reasons, chief among which is the placement of these signs at points where they are not needed, people have seen fit to ignore them repeatedly. There are numerous cases also where slow signs on particularly hazardous stretches of road may have been advantageous, but poor planning had seen fit to neglect their installation. Faulty planning in one case and an overdose of caution in another has, in general, caused the public to disregard this type of sign. Were the signs to include information as to <u>how</u> slow to proceed or <u>why</u> the restriction was present, it is probable that less failure to obey these signs would be prevalent. In the enlarged signs, such failures as have been experienced in the smaller ones will gradually be eliminated. On page 85 is illustrated an enlarged reflectorized SLOW sign, with speed limitation indicated. The number of speed limitations subject to this enlargement process is relatively limited. It is usually necessary to convey this message so boldly only on the ourskirts of communities where definite speed restrictions prevail, as has been done in this case.

Railroad advance WARNING or crossing signs have, in the past, been extremely prominent. The traditional crossbuck sign is an old and well-known example. However, there are numerous crossing that still require special treatment. In locations of high speed or hazard points the enlarged sign would be of material benefit. A great deal of the city railroad, and also rural railroad, crossings are being marked on the pavements with advance warning symbols as illustrated in the photograph on page 88. This warning symbol has been developed and is approved by the Joint Committee on Uniform Traffic Control Devices.

GUIDE or DIRECTIONAL signs serve their purpose in more ways than one. In the first place, the driver receives his direction, and usually mileage, to the city he has in mind. In the second place, the city or town whose name is placed on the directional sign has free advertising to the traveling public, a condition which any city is willing to promote. An example of the GUIDE or DIRECTIONAL sign is illustrated on page 89. Another form of the GUIDE or DIRECTIONAL sign is the plain Route Marking sign. This is probably best illustrated by the pictures on page 90. On page 91 is illustrated the same location prior to enlarged sign treatment.

Visibility and Speed as Involved in the Use and Application of Large Signs - The two principal elements involved in the interpretation of any highway signs are the speed of the traveling motorist and the range at which these signs are visible. The visibility of the signs includes both daytime and night visibility and is entirely dependent on the size of sign and letters, stroke and weight of lettering, color schemes employed, reflector button use, and placement of sign.

In a series of tests conducted by the Bureau of Street Traffic Research, Yale University, in 1938 - 1939, the legibility of signs was studied. For its purpose the Bureau procured letters (black on white background) possessing varied dimensions in height, width, and width of stroke. None of the letters exceeded six inches in height. In order to compute the glance or time values of the different series a convenient apparatus was set up consisting of a portable shutter and a white backboard upon which the letter or signs could be placed. With this backboard placed directly to the rear of the shutter it was possible to provide only split second readings of the copy under observation. Stations were marked off at intervals of twenty-five feet and, for the initial test, the maximum distance was restricted to 400 feet. To prevent the students from distinguishing the letters or words, through familiarity, the letters were scrambled, even to the extent that all syllables were eliminated.

It was obvious during the entire experimentation period, two days, that the "E" series in both the six and four inch heights was the most quickly identified. For instance, during the first afternoon's observation, some of the men were able to call out the correct letters (6 inch "E" series) from the four hundred foot mark, but when either the letter or the spacing was narrowed, there was an attendant misconception of the copy.

With the use of symbols, during both day and night observations, it was obvious that, due to slightly increased size and simplicity, these offered more actual glance value than did the letter signs. For example, in the daylight most the symbols could be recognized up to a distance of one thousand feet. But, when common words such as HILL and STOP were substituted, it was difficulty to be certain of the copy beyond five hundred feet. This despite the fact that the observers were more familiar with this type of sign than is the average motorist. The accompanying table (page 93) shows the reaction times manifested by the entire group of students in this original experiment dealing with recognition values. The following prominent results were obtained from this experiment.

1. The "E" series, normal lettering and spacing, was the most easily and readily discerned.

2. The narrowing of either the space between the letters or the stroke of the letter itself injured legibility.

3. That practically every sign requires one inch of copy for every fifty feet of distance between the observer and the sign itself. This in order to assure absolute legibility.

4. Symbols are more easily seen, at both long and short distances, than lettering or copy.

5. Most signs require more than "split" second observance before being recognized.

The results of this experiment demonstrate the need for increased letter and symbol sizes at longer distances and brings us directly back to the adoption of the enlarged sign where the vital factor is long range visibility. For example, consider a car traveling at the rate of 900 feet per ten seconds. The driver, his attention divided, has little leeway in which to interpret the signs or markings adjacent to the highway. Even under the most favorable conditions the six inch letter does not afford true legibility above four hundred feet.

SLOW SIGN - ENLARGED TREATMENT - DAYLIGHT

The slow sign location in its present position serves two purposes - (1) slowing cars because of the restricted sight distance around the curve and (2) slowing cars because of approaching a community.

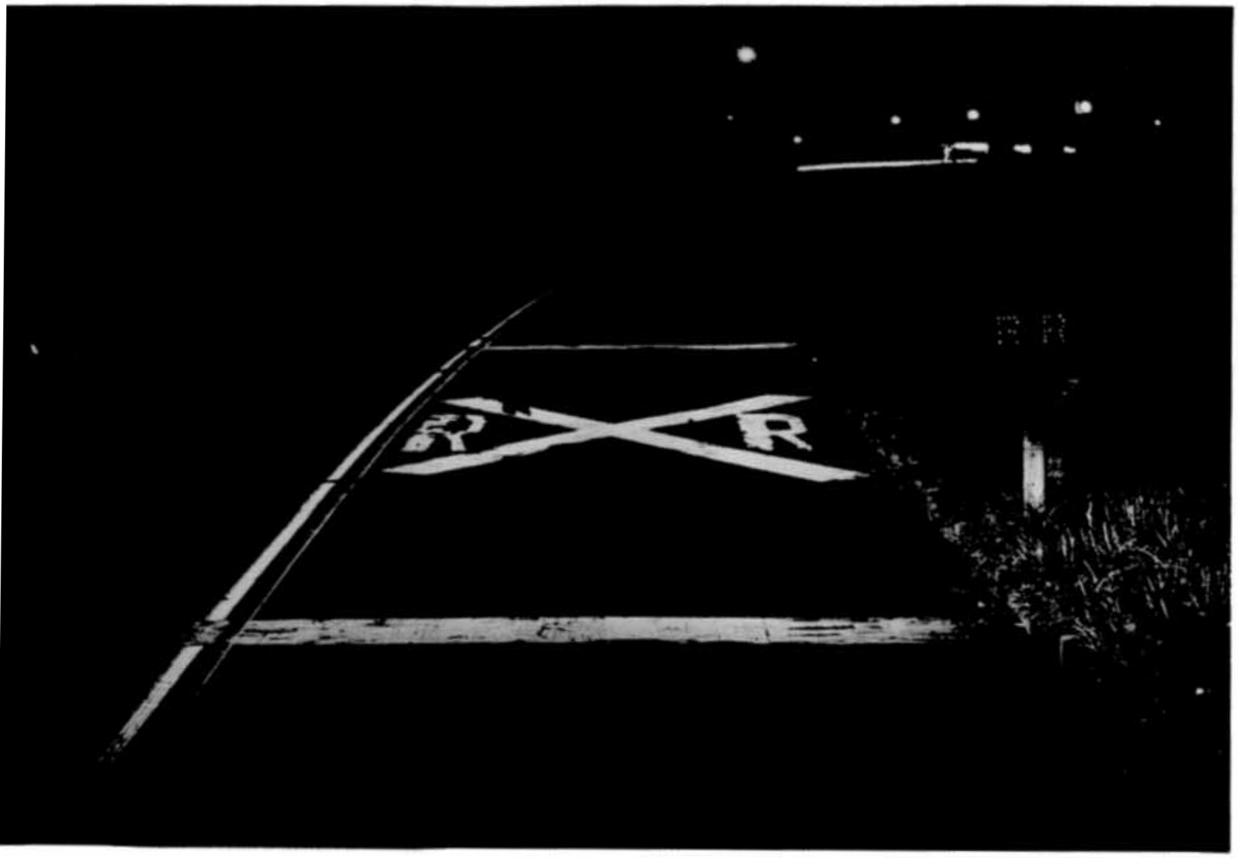
SLOW SIGN - ENLARGED TREATMENT - NIGHT

The same sign as that viewed on page 85.

The tables appearing on page 95 give the results that were obtained by the Yale Bureau of Street Traffic Research when words and syllables were presented for identification. Again, upon reference to this table, it is evident that the normal letters and spacing were the most readily comprehended. In this instance, the particular experiment was carried on under adverse weather conditions. The weather itself constituted a handicap, in addition to the fact that this was the initial attempt with the particular type of equipment. However, the uniformity of results and the consistent tendencies in all observers are proof that the results obtained can be accepted as nearly accurate visibility data.

It is readily perceived that Visibility and Speed are closely connected in the interpretation of highway signs and markers. Time, which is one of the chief factors in perception, is in itself directly dependent upon Speed. The operator proceeding at an excessive rate of speed has to concentrate more or give longer attention to the signs along the roadway than does the individual traveling at a moderate rate because of his divided and rapidly changing attention. By the same token the fast driver has less time in which to make a decision should an emergency arise.

Speed - It is generally conceded by traffic experts that on the open highway, where sixty percent of our accidents occur, most of this mishaps are due to the driver's ignorance of the limitations of human vision. Although the average driver may contend that the human eye can comprehend any situation even though moving at a high rate of speed, these same traffic experts advise that concentration increases as speed increases. In other words, the faster a driver goes, the more must he fix his attention in the direction in which he is going. In order to obtain perception it is also



PAVEMENT MARKING FOR RAILROAD GRADE CROSSING

This, an advance warning symbol, is the present standard of marking as approved by the Joint Committee on Uniform Traffic Control Devices.

THE ENLARGED DIRECTIONAL ROUTING SIGN

Note the comparative size of man and sign.

ENLARGED SIGN TREATMENT

Note the clear visibility - these signs are reflectorized for night driving safety.

INTERSECTION WITHOUT ENLARGED SIGN TREATMENT

This, the same intersection as that shown in the picture, page 90, shows the conditions prevailing before treatment. Note the illegibility of the various markers in the "Y" of the intersection. Note also the tire tracks of cars whose drivers have evidently been confused in their interpretation of these signs.

necessary to attain attention. As speed increases, the things to be seen each instant increase in number, and there is less time in which to perceive each.

Thus, if it can be made easier for the driver to perceive signs or markings when he is moving down the road at an advanced speed, then definite obstacles will have been cleared from our path. In short, if an operator is able to absorb completely the message on a sign or marker in one glance, he may then devote the remaining time to the attention of the highway itself.

It is common experience with all of us that, as we go into advanced speeds, and try to see the things on the side of the highway, we are likely to miss something that exists in the center of the highway, or vice-versa. Therefore, when our glance darts from one side or the other, it must come back with the message we are seeking. And if that message is a warning as to changing road conditions, then we would want plenty of time to react.

Authorities add to this opinion by stating, "Attention is active all the time that we are awake. Our attention may be concentrated -- as when we focus on some things that we are watching closely, or when we are thinking about a problem. At other times our attention is dispersed. Daydreaming, letting our minds wander, is a dispersed form of attention." This so called daydreaming, referred to by these authorities, is the rather unfortunate habit that many people slip into when driving familiar stretches of highway or after sitting behind the wheel for extended periods of time. Although, it may be looked upon as unimportant, under most circumstances, it is an accepted fact that such inattention is the contributing cause of many accidents. In order to "snap" drivers out of the apparent lethargy, it is often necessary to confront them with the unusual, that is, with an impressive sign or marker.

TABLE III

1. One Second Exposure (Using Shutter)

Distance	4" E Normal	4" E Close	4" C Close
300 ft.	2 perceptions	no perceptions	no perceptions
275 ft.	1 perception	2 perceptions	no perceptions
250 ft.	5 perceptions	4 perceptions	no perceptions
225 ft.	3 perceptions	5 perceptions	no perceptions
200 ft.	2 perceptions	4 perceptions	no perceptions
175 ft.	4 perceptions	3 perceptions	4 perceptions
150 ft.		1 perception	7 perceptions
125 ft.			6 perceptions
100 ft.			2 perceptions

Lettering used NSPACE LSAIOU AUSLHT

2. Prolonged Exposure (Without Shutter)

Distance	4" E Normal	4" E Close	4" C Close
350 ft.	2 perceptions	no perceptions	no perceptions
325 ft.	4 perceptions	no perceptions	no perceptions
300 ft.	2 perceptions	no perceptions	no perceptions
275 ft.	4 perceptions	no perceptions	no perceptions
250 ft.	3 perceptions	1 perception	no perceptions
225 ft.	3 perceptions	2 perceptions	no perceptions
200 ft.	1 perception	9 perceptions	no perceptions
175 ft.		3 perceptions	2 perceptions
150 ft.		2 perceptions	2 perceptions
125 ft.			4 perceptions
100 ft.			8 perceptions
75 ft.			3 perceptions

Lettering used WEUNPI IOSTWP ALITUP

(Difficulty apparently due to IT combination)

TABLE IV

Glance Results (unfamilar Syllables) - - 6" C Series

Syllable	First Glance	Second Glance	Third Glance
HONT	NO perceptions	4 perceptions	
LAS	1 perception	7 perceptions	
WEP	2 perceptions	7 perceptions	
HOL	NO perceptions	NO perceptions	
WAN	1 perception	4 perceptions	3 perceptions
TESP	2 perceptions	13 perceptions	3 perceptions
LANS	NO perceptions	1 perception	NO perceptions
THEP	1 perception	3 perceptions	2 perceptions
WOU	2 perceptions	12 perceptions	7 perceptions
WEH	3 perceptions	3 perceptions	5 perceptions

(A number of the men could not pick out the syllables even with a third glance privilege.)

Familiar Words

Word	First Glance	Second Glance	Third Glance
SLAP	1 perception	1 perception	No perception
THE	2 perceptions	6 perceptions	3 perceptions
POST	3 perceptions	8 perceptions	10 perceptions*
HAUL	NO perception	4 perceptions	1 perception
PEST	1 perception	10 perceptions	1 perception
NEW	2 perceptions	3 perceptions	4 perceptions
STOP	3 perceptions	2 perceptions	13 perceptions

(*Indicating that a number of the men comprehended the words after "getting" the phrase itself.)

These authorities support unhesitatingly the theory that at high speeds the mind is bound to concentrate on the moving surface in front. Despite this intense concentration the mind will wander, if only for a brief instance, and it is just such periods that allowances must be made for determining the full reaction time. Under certain conditions, this permits only another instant to grasp the full import of the roadside signs or indications. It is not implied that, at advanced speeds, the operator will never observe the smaller signs. On the contrary, it is entirely probable that familiarity with the shape of the marker or its general design will penetrate the mind of the driver immediately. On the other hand, there are those instances when the message or copy must be immediately conveyed to the man at the wheel regardless of previous knowledge or familiarity.

Concentration increases as speed advances, and as speed advances the point of concentration movesfarther away. In other words, the faster one travels, the farther ahead one attempts to see; thus the actual distance of the point of concentration increases as fast or faster than the speed of the car. The best conception of what this means is obtained from the following table relating to the focusing distance ahead for various speeds:

TABLE V

RELATION OF SPEED TO FOCUSING DISTANCE

Speed	Focusing Distance Ahead
45 M.P.H.	1270 feet
50 M.P.H.	1430 feet
60 M.P.H.	1800 feet
65 M.P.H.	2000 feet

This table clearly shows that the eyes are continually jumping ahead in order to compete with increasing velocity.

It may not be practical to construct signs which will satisfactorily meet the focal distances as set out in the above table, but these signs can be made sufficiently visible to assure the maximum of response from the motor vehicle operators.

There are numerous other limitations on the human eye, that is, fading of the foreground at high speeds, limitations of peripheral vision (figures 11 and 12, page 99), fallacies which accompany space perception, such as effort to determine on-coming car speed, and in addition the astounding fact that the eye has no perception except when focused. Thus the time expended in glancing from one object to another along the roadway is lost. These are only additional factors which uphold the argument that high speeds demand, and should have, visual aids. Certainly a readily discernible sign used under conditions warranting its use is a major steps in the right direction.

Visibility - Considered as one of the most comprehensive studies on sign effectiveness and the visibility of standard luminous and non-luminous highway signs was that study undertaken in 1933 by the U. S. Bureau of Public Roads in cooperation with the National Bureau of Standards. The experiment was designed primarily to cover the following phases:

1. Personal observations of standard signs having different color combinations as between background and legend in which letters of various standard sizes, without reflector buttons, were used.

2. Night observations of signs equipped with reflector buttons.

3. Daylight observations, made of these reflectorized signs, to determine what effect, if any, there was on the legibility due to the reflector buttons appearing on the black copy.

A tachistoscope, consisting of two major units, namely, a screened eye-piece with two shutters moving in parallel vertical planes and an A frame or easel supporting a pendulum by which the time interval is regulated and controlled, was used to carry on the experiment.

In choosing the field for operations, great care was taken in selecting a section of roadway which would represent the average background encountered on a typical highway. Observations were taken at 200, 300, 350, 400 and 500 feet, with observers themselves ranging in age from 17 years to 70. All tests were made with signs of standard dimensions as adopted by the Uniform Committee of the American Association of State Highway Officials.

Although these tests do not pertain directly to the use or value of enlarged signs, the results obtained are sufficient to demonstrate the limitations of smaller copy. They are presented for this reason.

For the tests on non-reflecting signs, seventy observers were used to make a total of 4,563 observations. The time interval for legibility ranged from 0.6 to 1.0 seconds. These results uphold the theory, previously advanced, that a certain amount of time is required to absorb the actual meaning of the copy. Not very much, it is true, but sufficient to take up from fifty to eight-eight feet of traveling distance.

The transposition of letters or legend, used in the tests conducted by the Bureau of Roads, is of particular interest. If it were apparant that the observer could not read the six inch letter, for example, in a 0.5 interval, then the eight inch copy was flashed before him. Invariably there was faster recognition with the larger lettering, even when unfamiliar signs were used.

The average of the observations at all distances and from all time intervals established the following relative value:

1. Readings of the black on white combination were 75 percent correct.

2. Readings of the black on yellow were 66 percent correct.

3. Readings of the white on black were 59 percent correct.

At the maximum distance of 500 feet, the following data were obtained: on the large SLOW sign at 1.0 second, 42 percent correct reading resulted from black on white; 58 percent from black on yellow, and 38 percent from white on black. At this point several observers were asked if the copy was clearly read or if the identification was made from the picture as outlined by the length of the words. A number of the observers claimed that they actually read the words, but it is thought that a number probably read the shorter words and guessed at the longer. In comparing the readings of the zone signs at 0.6 seconds against the 8 inch copy contained on the SLOW sign, it was found that there was a one percent greater efficiency of the larger letters over the smaller in the black on white combination and an eight percent increase on the black on yellow. (See Table 6A, page 102).

It is therefore evident that color combinations enter into the subject of both visibility and legibility. However, the color combinations, in order to be a decided favorable factor, probably will be found to vary considerably with the section of the country and with the visual capabilities of the drivers. It is logical to assume that the color in the natural surroundings of that section in which the signs are to be placed must be considered. It will therefore be an added precaution for such states as those in the mid-west and west where the natural colorings are a blend of grays and browns, to experiment further with the expansive

FIGURE 11

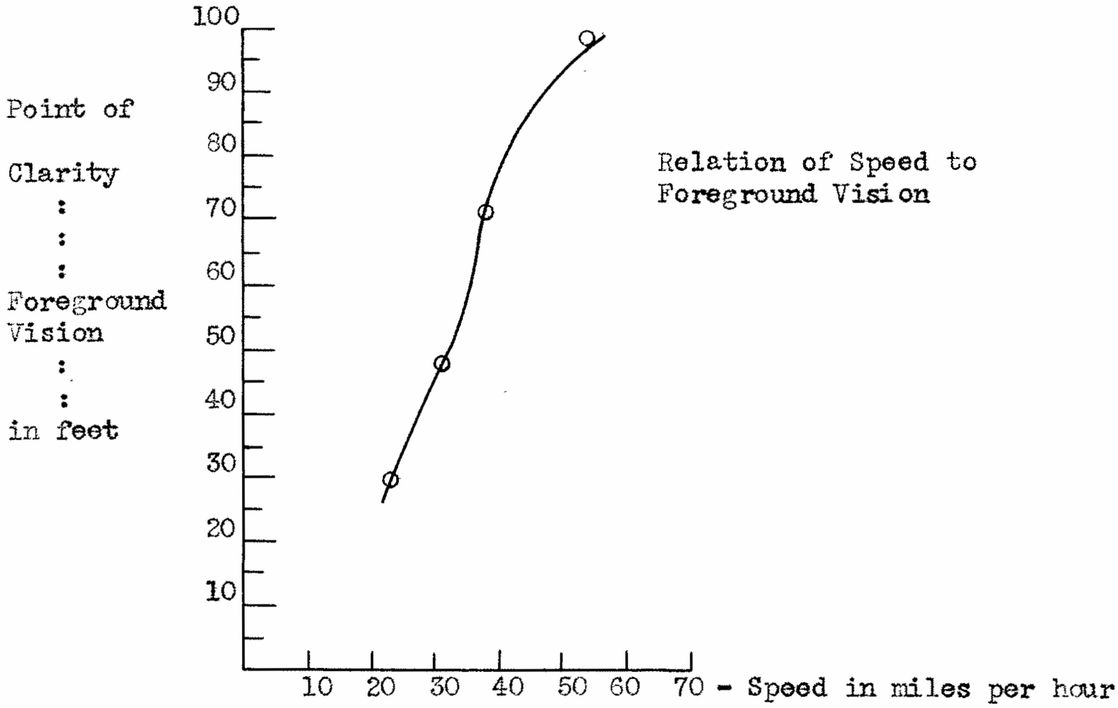
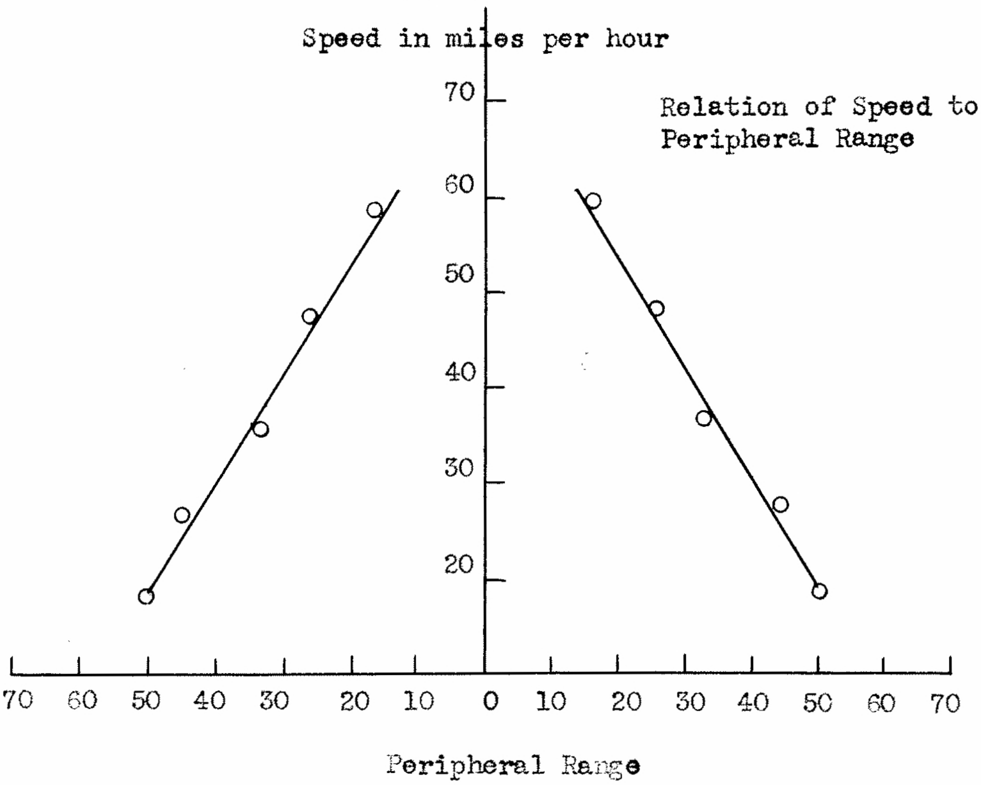


FIGURE 12



background color before installation of too many enlarged signs. The standards as contained in the Manual on Uniform Traffic Control Devices appear to strike an acceptable medium by recommending varied combinations for the different types of signs. Whether these will prove suitable for big sign adaption, is as previously mentioned, a matter of experimentation.

Another phase of the Bureau tests was to take night observations of unreflectorized signs. It was discovered, in this case, that it was useless to attempt to read the daylight signs at a distance of more than 200 feet. Even at this distance, it was impossible to be absolutely certain of the copy appearing on the sign. (See tables on page 106). The study is convincing with respect to the necessity of reflectorizing all signs subject to night use. In this reflectorization, however, care must be taken so as to not create a glare or, as some put it, an indistinguishable mass of light emanating from the sign. The latter is particularly true of over-sized installations where large buttons are used. In some instances such signs have been installed so that traffic coming over a hill or around some obstruction has lighted up the large sign so abruptly that the tendency has been for accidents to increase rather than to decrease. In such cases, because of the excessively large reflector buttons, the illumination has been of such a degree that drivers actually believed that they were already into the hazard, whereas they were probably as far as a thousand feet away. Mention is made of the existence of such signs because too much care cannot be exercised in properly locating the super-sized signs or in using extreme caution in selecting the proper size for a particular section of roadway.

In experiments carried out, utilizing standard reflectorized signs, it was found that appreciable results were obtained up to a distance of 350 feet, a rather short distance to permit emergency stopping at fifty to sixty miles per hour. It was further learned that the 0.76 inch button produced superior results as compared to either the larger or the smaller size buttons (on the smaller signs). This factor is extremely important in the illuminating of the super signs, as it has been disclosed that the comparatively small buttons, 0.76 to 0.95 inches, can be used satisfactorily on the broad stroke of the larger symbols or letters. The "jumbo" buttons are efficient up to a certain point, and then the reflection has a tendency to blur.

The reflectorized signs, during daytime observation, indicated that the legibility had been measurably decreased because of the presence of the buttons. However, the experiments disclosed that there was very little difference in the use of black or white copy, and that any deficiency created by the buttons during the day is off-set by the maximum light and visibility which is in evidence during that period.

These experiments, carried on under the supervision of the U. S. Bureau of Public Roads, showed conclusively the value of certain color combinations and reflecting units over others, thus providing a reference point or basis in the adoption and popularizing of the large sign. However, as mentioned previously, when consideration is given to super signs, these factors are all subject to proof of their value through actual installation and tests in the field. The principal reason for bringing out the experiments of the Bureau is to point out the results

TABLE VI A

COMPARATIVE VISIBILITY AT MEAN DISTANCE (500 FT. STATION) DAY

Sign	Size of Letter	Color Combination	Percentage Correct Readings
SLOW	8 x 3/16 in.	Black on white	42
		Black on yellow	58
		White on black	37
STOP	6 x 1 in.	Black on white	30
		Black on yellow	47
		White on black	30
CURVE	6 x 7/8 in.	Black on white	35
		Black on yellow	39
		White on black	37
ZONE	5 x 5/8 in.	Black on white	33
		Black on yellow	44
		White on black	37
SLOW	8 x 3/16 in.	Black on white	34*
		Black on yellow	52*
		White on black	37*

*Decreased time interval

TABLE VI B

COMPARATIVE VISIBILITY AT MEAN DISTANCE (350 FT. STATION) DAY

Sign	Size of Letter	Color Combination	Percentage Correct Readings
SLOW	8 x 3/16 in.	Black on white	78
		Black on yellow	83
		White on black	72
STOP	6 x 1 in.	Black on white	64
		Black on yellow	78
		White on black	77
CURVE	6 x 7/8 in.	Black on white	62
		Black on yellow	64
		White on black	63
ZONE	5 x 5/8 in.	Black on white	62
		Black on yellow	64
		White on black	63
SLOW	8 x 3/16 in.	Black on white	56*
		Black on yellow	71*
		White on black	63*

*Decreased Time interval

secured with various color combinations and reflector units in the smaller signs, and to indicate the way for added research with the super or enlarged sign treatment.

It might be added here that some few states have experimented to some extent with the enlarged sign already. To all concerned it has become evident that the effectiveness of the over-size installations is contained in the practice of using them only where the situation demands one. This means, of course, that when an installation of this kind is contemplated -- every item connected with it -- color, reflector units, location, materials, and even the supporting framework -- is given careful consideration. In some localities of one or two states the over-size sign has become the rule rather than the exception, thereby practically defeating its own purpose, for the effect is probably no more than if a continous installation of small signs were used.

Experiments with the Enlarged Sign as Conducted by the State of Michigan - In cooperation with the U. S. Bureau of Public Roads, the State of Michigan, authorized by Mr. Murray D. Van Wagoner, carried on certain tests with the enlarged signs. A complete statement of the test as submitted by the Michigan State Highway Department follows:

- Stop Sign Study -

The necessity of requiring vehicles to make full stops before preceeding at locations of unusual road or traffic conditions has been quite generally recognized. A number of devices have been employed to effect such vehicle stops, but the most commonly used device is the octagonal STOP sign. It is also quite generally known that in spite of the use of stop signs, vehicles in considerable numbers are not stopped and, too frequently, such vehicles become involved in traffic conflicts with variable consequences. STOP signs have been given legal significance, and enforcement, in connection with violations of the stop law, is known to be effective in improving obedience. Non-observance may also be due to the driver's ignorance of the existing signs because of improper visibility or other defects due to poor maintenance.

It was with a thought of determining to what extent the design, color and size of STOP signs may affect obedience under conditions in which enforcement is either constant throughout or totally absent that the field experiments described below were conducted.

<u>Description of Location</u> - The location selected for this study was an intersection on Michigan Route No. 9, approximately 1-3/4 miles south of the Lansing city limits, known as Jolly Corners. The crossroad is and 18 foot black top county road carrying a volume of approximately 600 vehicles per day. It was assumed, as it would probably be in most locations, that a large portion of this traffic was local in character. Michigan Route No. 9 is a 20 foot concrete through highway at this location, and the traffic observed was that which entered or corssed M-9 from either direction on the aforementioned county road. The posts carrying the STOP signs were located approximately 30 feet from the intersection of the lateral boundary lines of the intersecting roadways and six feet to the right of the roadway, and the centers of the signs, when installed on these posts, were about four feet above the crown of the roadway. The view of M-9 from both approaches on the county road was somewhat limited because of the slight up-grades and the buildings on three of the four corners of the intersection. However,

TABLE VII

Night Observations of Luminous Signs

300 ft.

Sign	Size of Letter	Percentage of Correct Readings 0.95 in.	0.76 in.	0.58 in.
SLOW	8 x 3/16	60%	85%	75%
STOP	6 x 1	30	60	60
TURN	6 x 1	35	55	15
CURVE	6 x 7/8		45	20
STOP	6 x 1	35	45	40
SLOW	8 x 3/16	35	35	40*

*Reduced time interval

TABLE VIII

Comparative Readibility of Liminous and Non-Luminous Signs Under Daylight Conditions - Showing Average percent of Correct Interpretations

Reflectorized & Daylight Signs	Percentage of Correct Readings 200 ft.	300 ft.	350 ft.	400 ft.
0.95 in buttons	55	68	31	22
0.76 in buttons	74	63	25	30
0.58 in buttons	64	67	27	25
Daylight Signs	92	65	70	43

Above table indicates marked effect of reflectors on daytime visibility of copy.

TABLE IX

Comparative Legibility of Letters Equipped with Reflectors - Night Observance

Size of Button	Color Combination	Percentage of Readings Correct
0.95	Black on white	43%
	White on black	45%
0.76	Black on white	49%
	White on black	47%
0.58	Black on white	45%
	White on black	46%

the STOP signs themselves were so located that they could be seen from a distance of at least eight hundred feet.

Method of Conducting Study - Four changes of signs were used during the study and consisted of the following:

1. Two old, unreflectorized 24 in. STOP signs.
2. Two new, reflectorized 24 in. STOP signs.
3. Two new, reflectorized 36 in. STOP signs.
4. Same as No. 3, observed after a 30 day lapse of time.

On each change of signs, 1,000 observations were taken, consisting of 500 during daylight and 500 during the "after dark" period. The observer was stationed at some distance from the intersection so that he could easily observe the behavior of all vehicles entering the intersection, yet he was not readily visible to the drivers of such vehicles. All vehicles entering the intersection from the crossroad at a speed of 10 miles per hour, or less, were considered as having stopped, and all vehicles entering at a speed greater than 10 miles per hour were regarded as having violated the STOP regulation. The success of the study depended to some extent on the judgement of the observer in determining the entering speeds. However, the same observer was used throughout the entire study so that, if there was any error in his judgment of speeds, it would apply equally to all observations taken and the relative obedience to the various signs used would be in error by the same amount.

Step No. 1. The signs used in this part of the study were, as mentioned previously, two old, unreflectorized 24 in. STOP signs. They were badly in need of paint and, in general, were in poor repair. Of the 500 vehicles observed during daylight, 7 percent entered the intersection at speeds greater than 10 miles per hour, and at night, 17.6 percent of all vehicles disobeyed the STOP signs.

Step No. 2. In this part of the study two new, reflectorized 24 in. signs were used. Obedience to these signs was very little, if any, better than to the signs used in Step No. 1. This, inasmuch as daylight disobedience amounted to 8.6 percent and night disobedience to 16.6 percent.

Step No. 3. Two new, reflectorized 36" STOP signs were used in this part of the study, and it was found that the daylight disobedience dropped to 4 percent, as compared to 8.6 percent with the 24 in. signs, and the night disobedience dropped to 4.2 percent as compared to 16.6 percent with the smaller signs. This showed a decrease of 50 percent of daylight disobedience and 75 percent of night disobedience. (A truly remarkable improvement for this type of treatment.)

Step No. 4. It was believed that the large signs used in Step No. 3 produced a rather startling effect on the vehicle drivers resulting in such a low percentage of disobedience. It was also concluded that, since traffic at this intersection was mostly local in nature, motorists would soon become accustomed to the signs and disobedience would again increase towards the former figures. This, however, was not the case, as the disobedience dropped still further, to 2.6 percent during the daylight hours and to 3.8 percent at night, after a 30 day lapse of time.

The following summary indicates the disobedience observed in each of the four steps of the treatment.

		Daylight	Dark
1.	Old, unreflectorized 24 in. sign	7.0%	17.6%
2.	New, reflectorized 24 in. sign	8.6%	16.6%
3.	New, reflectorized 36 in. sign	4.0%	4.2%
4.	Same as No. 3 after 30 day lapse	2.6%	3.8%

From the above figures, it would be concluded that the 36 in. reflectorized STOP sign would be the proper one to use on all rural intersections wherever such signs are necessary. These data lend strength to the contention that many non-observances, of which some result in accidents, are due to a lack of prominence of signs or of a sufficient appreciation of their implications.

The Michigan installation is a splendid example of what can be achieved with proper treatment. The engineers, in this case, recognized that a decrease in the disobedience ratio was needed at the particular intersection in question, and through a simple but effective method of increasing the over-all dimensions of the sign by twelve inches (copy proportionately enlarged) they were able to achieve results which were very gratifying.

It must be remembered that the STOP sign is anything but popular with the driving public, but if a city or state government is able to affect a satisfactory treatment at locations where the traffic regulations have not been consistently obeyed, then the restriction should willingly be accepted by everyone.

The statement has often been made that the placement of signs indicated weakness or shortcomings in the road itself. There is truth in this, but until we are better able to construct highways of perfect design and without any conceivable defect, it will be necessary to resort to such mediums as signs to protect the motorist. One might go even further and insinuate that a super sign indicated a conspicuous failure. The only answer to this is that these unfavorable conditions do exist and, as in the case of Michigan, it is up to the engineer or others connected with the road department to undertake the most satisfactory solution under the existent conditions.

The next experiment carried on by the Michigan Department was then done with the use of an ADVANCE WARNING SIGN, reading as follows: "WARNING STATE HIGHWAY 500 FEET". This observation was also carried on in cooperation with the U. S. Bureau of Public Roads. The report as submitted by Commissioner Van Wagoner follows: [3]

"The value of signs, as regards the amount of observance obtained, has, up until the present time, largely been a matter of conjecture. It is recognized that many studies have already been made to determine the observance or obedience value of signs, but the number of such studies as compared to the large number of different signs, is relatively insignificant. For the greater part, then, signs have been designed and installed without concrete evidence that the desired results would be obtained.

"On our present highway systems, stops are generally required of vehicles entering or crossing main or trunkline highways from roads of less importance. These stops are usually affected by signals or the standard octagonal STOP sign. In many instances on rural highways, because of restricted sight distances, these STOP signs are not visible for a distance great enough to permit the motorist to make a comfortable stop before reaching the intersection. (This is particularly true in rolling or mountainous country where the sight distances are continuously impaired). Such a condition often results in a STOP sign disobedience which, in turn, may result in accidents of varying degrees of severity.

"This particular study was made in an attempt to determine the value of warning signs giving advance notice of such required stops. The location

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[3] U.S.Bureau of Public Roads.

selected for the study was an intersection on Michigan Route No. 144, approximately 1/4 mile south of U. S. Route No. 16 and 1/2 mile east of the Lansing City Limits. Both roads forming this intersection are eighteen foot black top roads and the crossroad on which the traffic is stopped, is a county road carrying a traffic volume of approximately eight hundred vehicles per twenty-four hours.

"The STOP signs used at the intersection were 24" reflectorized signs and were placed approximately 30 feet from the intersection of the lateral boundary lines of the intersecting roadways and six feet to the right of the pavement edge. The centers of the signs were about four feet above the crown of the highway. The advance warning sign used in this instance was a 48" WARNING STATE HIGHWAY 500 FEET, sign. These markers were installed about 500 feet in advance of the intersection and some six to seven feet from the edge of the roadway. The results of this observation were calculated in terms of obedience to the STOP signs both before and after the installation of the advance warning signs.

"On both the before and after studies one thousand counts were taken, consisting of 500 during daylight and another 500 during the dark hours of the day. The observer was stationed at some distance from the intersection so that he could easily perceive the behavior of all vehicles entering that particular locality, yet, again, he was not readily visible to the drivers of such vehicles. All vehicles entering the intersection from the crossroad at a speed of 10 miles per hour or less, were considered as having stopped, and all vehicles entering at a speed greater than 10 miles per hour, were regarded as having violated the regulation. The success of the experiment, as in the previous case, depended to some extent on the judgment of the observer in estimating the entering speeds. However, the same observer was used throughout the entire study so that any error in judgment of speeds would apply equally to all observations taken and the relative obedience to the same in both before and after observations, would be in error by the same amount.

"The following summary indicates the disobedience to the STOP signs observed in each of the two steps of the study. All percentages are based on five hundred observations:

	Disobedience	
	Daylight	Dark
Before warning sign installation	5.2%	11.6%
After warning sign installation	4.2%	3.6%

"From the above figures, it may be seen that the warning sign installation reduced the STOP sign disobedience by some 19 percent during the day and by 69 percent during the night. These reductions are conclusive evidence that, when a stop sign is not plainly visible from a safe stopping distance, the use of the advance warning signs WARNING STATE HIGHWAY 500 FEET, is fully justified."

As a result of these two experiments carried on by the State Highway Department of Michigan, the following conspicuous facts which are of interest in the application and use of enlarged signs are brought to light:

1. That the average motorist will pay attention to a sign of unusual significance, if such a marker is correctly placed and of satisfactory construction.

2. That reflectorized signs, as in the previous study, will show even better results than those obtained with the improved sign during daylight observance.

3. That the average motorist, contrary to certain beliefs, will give attention to improved pre-warning signs.

4. That the "novelty" of these signs did not wear off after thirty days.

Although not directly pertaining to the value or use of enlarged signs, these experiments and results obtained are set forth with the view in mind of demonstrating the limitations of the smaller copy with respect to certain conditions. In the final analysis the response to color combinations or reflectorization is the same in one as in the other, the larger sign intensifying both color combinations and reflectorization, making them more visible over a longer distance.

The ability to see is supremely important in the safe and effident operation of the highway transportation system. High visible treatment with signs will add to that operating efficiency of the highway. It is suggested that the use of enlarged signs lead to the haphazard placement of these signs on our highways, but rather, that a satisfactory schedule be worked out whereby such signs will be applied only to those points definitely in need of them. Such requirements can be carefully determined by research and study, as was done in the case of Michigan.

SUMMARY

Highway engineering and highway planning, now hand in hand, are solving the cause of accidents on our highways. Together, these two must use those means advanced in this thesis for eliminating highway hazards which are still prevalent and which are still endangering the safety of the driving public.

These facts, which may seem so simple to us now, must be diligently studied and analyzed by the competent engineers of a well-organized Highway Planning Survey. It is only through this means that dangers in traffic movement can be removed. Through the measures summarized below, the dreaded traffic hazard can be controlled.

1. A competent crew of engineers must make a survey of the critical features of the highways. This survey must include all excessive grades and curves, all superelevations, all limited sight distances and their causes.

An analysis of the compiled data used in conjunction with accident report data and traffic count data on these same roads will reveal the hazards to traffic.

2. Proper use of centerline striping and additional striping in no-passing zones where sight distance is restricted, will usually tend to remove the hazardous condition. Where this striping is found to be disregarded by numerous drivers, it becomes practicable to widen the roadway through the hazardous section and to install the medial divider, a physical divider between the opposing streams of traffic.

3. Overloading a highway with traffic causes traffic congestion, confusion and accidents. Planning Survey data can adequately be used as explained in this thesis for determining the relative need for widening a

two-lane road.

4. Even with an increased number of lanes, and even though striping and medial dividers may be used, the driving speed of the present car makes impractical the use of normal road signs where danger spots still remain. To compensate for the present day speed of vehicles the motorist must be able to read the warning sign in sufficient time to react. The only answer to his need is the enlarged super-sign, sufficiently large to permit of easy reading at such a distance as will be necessary for the driver to drive his car, under control, through the danger spot.

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